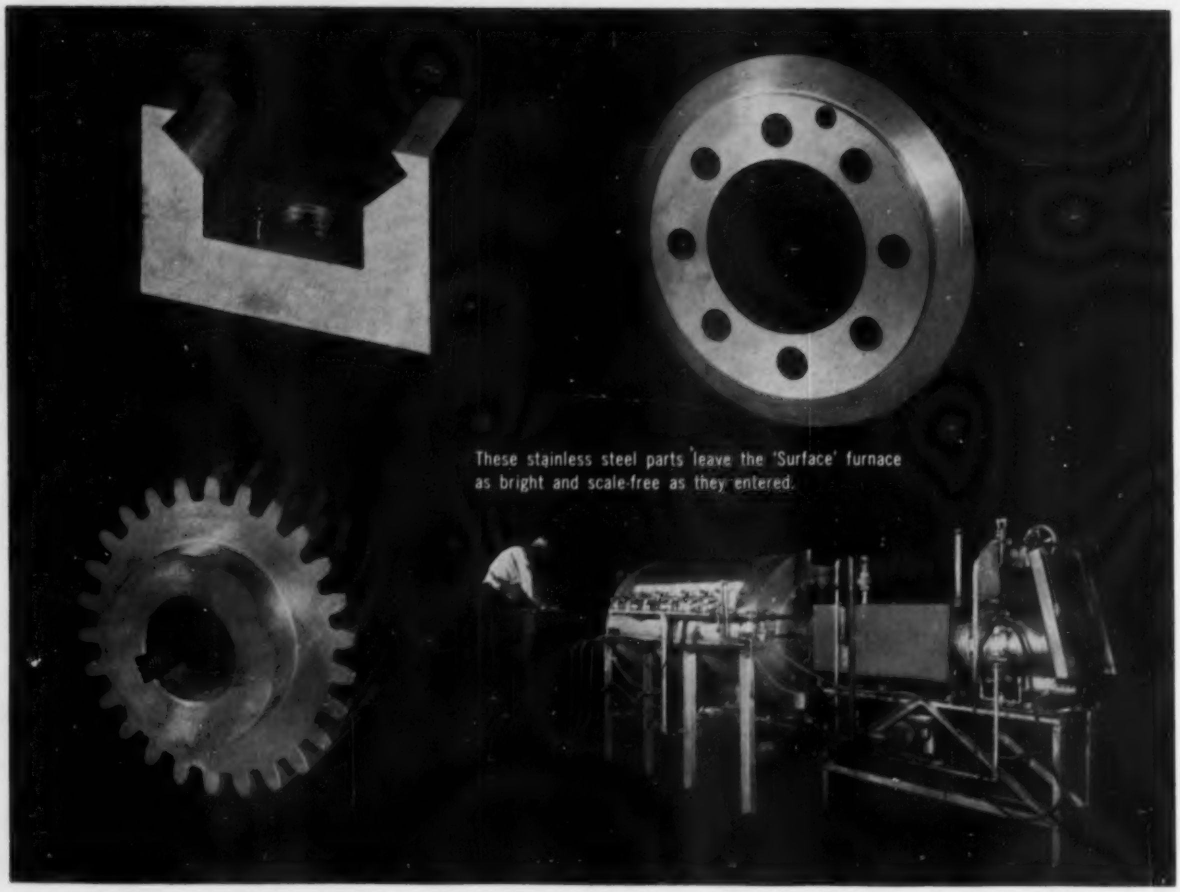
25TH ANNIVERSARY

METAL PROGRESS

SEPTEMBER • 1955



bright hardened stainless sells!

you can really sell bright hardened stainless and other high alloy steels, because they save money for your customers.

this has been demonstrated by the people at Syracuse Heat Treat Co., Syracuse, N. Y. In the two years since they installed this 'Surface' high temperature muffle furnace, they have sold their customers savings—cost cut $1.87 on one part . . . hand stoning operation cut from 30 to 5 minutes on another . . . delivery in half the previous time . . . tighter specifications met.

and you earn yourself, as the Syracuse people found out, because the furnace delivers parts clean and bright, and eliminates costly, time-consuming descaling operations. The market is good for the premium product this furnace permits. Why not tap it now?

write for the story on bright hardening stainless

Surface
HEAT TREATING EQUIPMENT

SURFACE COMBUSTION CORPORATION, TOLEDO 1, OHIO

Metal Progress

Volume 68, No. 3

September . . 1955

Silver Anniversary Issue

The front cover is a reproduction of the first cover of Metal Progress, published in September 1930.

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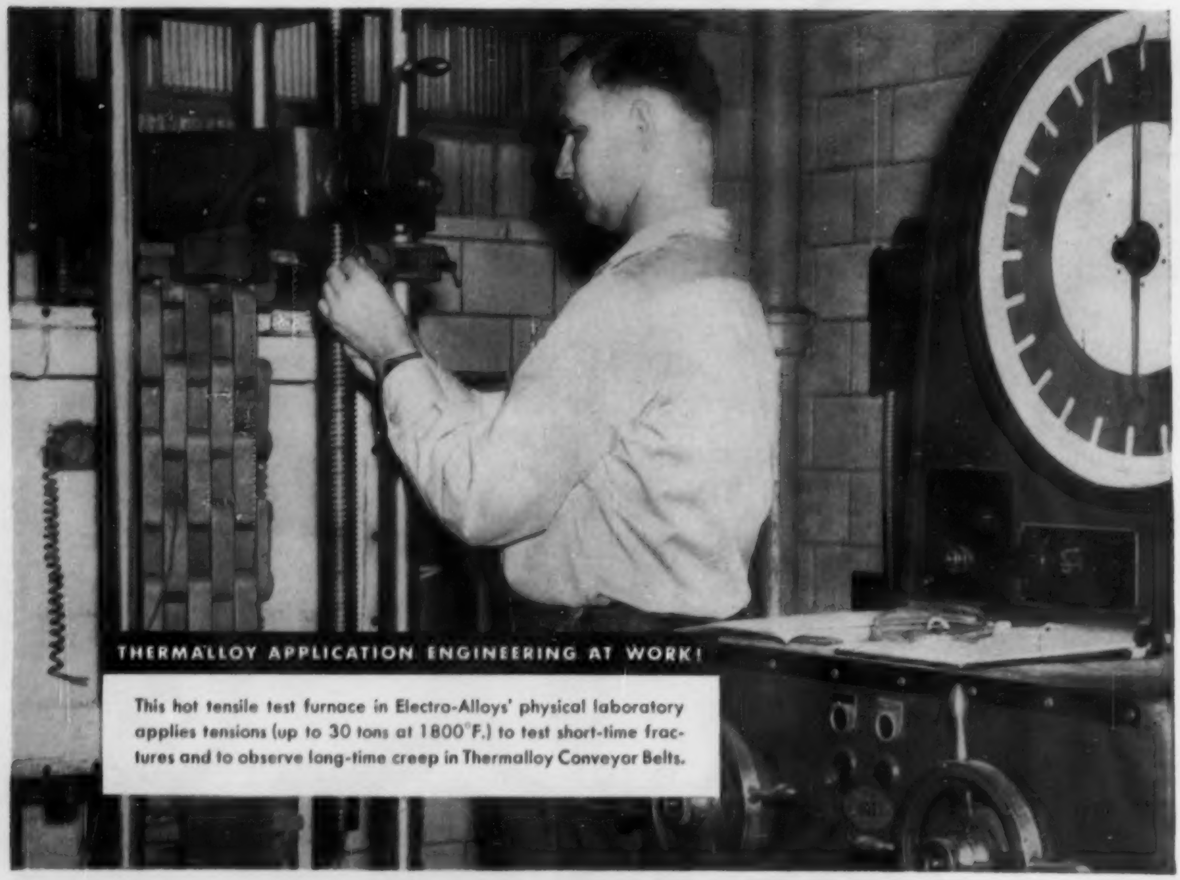
**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification.*



THERMALLOY APPLICATION ENGINEERING AT WORK!

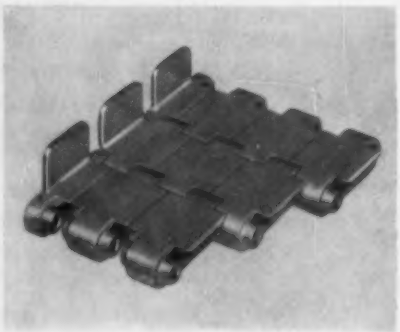
This hot tensile test furnace in Electro-Alloys' physical laboratory applies tensions (up to 30 tons at 1800°F.) to test short-time fractures and to observe long-time creep in Thermalloy Conveyor Belts.

A miniature furnace to test theories!

Service life of a heat-treating furnace conveyor belt may be affected by so many variables, i.e. uneven loading, misalignment, temperature differentials, etc., that proper design, highest quality and the right material are of utmost importance.

At Electro-Alloys, a staff of engineers and metallurgists are constantly studying these factors in the physical testing laboratory shown above. A hot tensile test furnace is continually in use subjecting Thermalloy* conveyor belts to various combinations of loading and temperature. In this way, design theories developed by our engineers are tested and highest possible quality standards are maintained to insure production of furnace conveyor belts that will be the ultimate in trouble-free operation.

Electro-Alloys also applies engineering and metallurgical know-how in the production of heat-resistant Thermalloy castings for other furnace parts such as sprockets, idlers, skid rails or rollers, crossbeams, wall boxes and radiant tube assemblies. For complete information, call our nearest representative or write for Thermalloy Conveyor Belt Bulletin T-241, Electro-Alloys Division, 6002 Taylor St., Elyria, Ohio.



To meet extra-severe operating conditions, a Thermalloy Heavy-Duty Conveyor Belt was developed. This partially assembled belt shows the short integral cast pins that eliminate "crank-shafting."

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION
Elyria, Ohio

*Reg. U. S. Pat. Off.

Metal Progress

Contents Continued

Biographical Appreciation

Data Sheet

Digests of Important Articles

Departments

This 25-year-old message is still sound reading

We'd like to call your attention . . .

. . . to a few facts about this ad which appeared in Metal Progress 25 years ago.

We still market all but one of the six heat treating salts described here . . . improved by research over the years.

To this list have been added salts for carburizing, for high speed steel, for martempering, for lead bath patenting, for brazing . . . processes developed during the quarter-century of progress in metallurgy.

Houghton has more than kept pace. Its salts, carburizers and quenching oils are your best buy for safe, speedy uniform heat treatment of today's metals.

Prove it by using them. Get latest salt bath catalog from the Houghton Man, or write E. F. Houghton & Co., 303 W. Lehigh Ave., Philadelphia 33, Pa.

SUPERIORITY!

HOUGHTON'S

Liquid Baths for the Heat Treatment of Steel . . .

Melt quickly and heat more rapidly.

Very fluid; insuring more rapid heating and lower carry-over losses.

Higher specific heat which allows more work to be heated in less time.

Specially purified; they contain no inert matter to form sludge.

So carefully blended and purified that they cannot attack the pots or parts.

Work is clean, bright and uniformly hardened—no scale—no soft spots.

Innumerable field tests by Houghton Engineers show that Houghton's Liquid Baths have longest life and lowest consumption per ton of parts.

No. 275 DRAW TEMP

For low-temperature tempering. Melts rapidly at 275° F. Usable working range 350-1200° F.

+ +

No. 6 LIQUID HEAT

Produces a very thin and very hard case on the work by a combined carburizing and nitriding action. Melts quickly at 1050° F. Usable to 1650° F.

+ +

No. 300 LIQUID HEAT

Forms a clear solution when melted; is very fluid and heats more rapidly. Has no carburizing action. Melts at 1050° F. Usable to 1650° F.

N. D. LIQUID HEAT

N. D. means non-decarburizing. This product will neither carburize nor decarburize the work if it is treated regularly with Houghton's Salt Bath Rectifier. Melts at 1200° F., usable to 1700° F.

+ +

HOUGHTON'S SURFACE HARDENING BLOCKS

Are one-ounce blocks which melt at 1200° F. and are usable to 1700° F. The bath has a rapid carburizing action and produces a hard, tough case.

+ +

HOUGHTON'S SURFACE HARDENING POWDER

Is made by powdering the Surface Hardening Blocks, and is intended for use where a product in powdered form is more desirable. It is used extensively for sprinkling on parts in an open furnace to produce a thin but very hard case.

E. F. Houghton & Co.

PHILADELPHIA • *And All Over the World*

As I was saying...

HERE is the third installment of my personal highlights of the Metallurgical Societies Meeting in Europe. The first installment recorded the conferring of Honorary Membership in the British Iron and Steel Institute on you and your Secretary, while the next one told of the invitation to the Instituto del Hierro Y del Acero that I read at the General Assembly of the Institute at its final meeting in Madrid. But here I have a confession—I did not present the invitation myself. It was read (in Spanish) to the meeting by the president of the Institute. I never did get to Spain as I had planned. The day I was to entrain for Madrid found me ambulancing to the American Hospital in Paris, where I spent 16 days. Then I recuperated for 12 days more on the Côte d'Azur. The two ulcers the doctors found have now been tamed, and both Uno and Duo, while always with me, are nevertheless as quiet as Vesuvius.

From the London meeting, the 270 members of the conference boated and special-trained to Dusseldorf for the week in Germany. The opening plenary session was held in the Residenz-Theater on June 9, when President Hermann Schenck of the Verein Deutscher Eisenhüttenleute and President Ing. P. Brenner of the Deutsche Gesellschaft für Metallkunde presented words of welcome and reports on the status of the German ferrous and nonferrous industries. President Brenner presented your Secretary with Honorary Membership in the Deutsche Gesellschaft für Metallkunde, including in the citation that "the honorary membership was granted on the basis of his services for the fostering of international conferences for the scientist in metallurgy". The presidents and the secretaries of the two host societies were conferees to the First World Metallurgical Congress in Detroit in 1951.

From Dusseldorf, the special train landed us in Liège (Belgium). We were immediately transported to Le Mosan, where a reception was held and luncheon served to us as guests of the metal industry of Belgium. The sponsors of the meeting were the University of Liège and the Centre National de Recherches Métallurgiques. All graduates of the Engineering School of the University of Liège become members of an association of engineers, which in turn is the "engineering society" of Belgium. At the luncheon meeting, the President-General, Monsieur F. Campus, presented to you and your Secretary a medal and diploma of "Membre d'Honneur, Association des Ingénieurs Sortis de l'Ecole de Liège", a distinguished honor greatly appreciated and acknowledged.

From Liège to Paris in a five-hour spin to meet the next morning at the Sorbonne's famous assembly room for the opening session of the conference under the auspices of the Société Française de Métallurgie. President Raoul de Vitry welcomed the visiting metallurgists to France, and a cordial response was given by A.S.M.'s President Roberts. At the close of this meeting, the honors were distributed and you and your Secretary received a medal commemorating his election to honorary membership in the Société Française de Métallurgie.

And so, dear friends, when you visit headquarters in Cleveland, I'll be happy to guide you to the A.S.M. Memorial Room where the certificates and medals will be housed. They are your medals. They all were given in recognition of A.S.M. achievements, and you, the members, are responsible for A.S.M. accomplishment.

Let's keep up the good work!

Cordially,

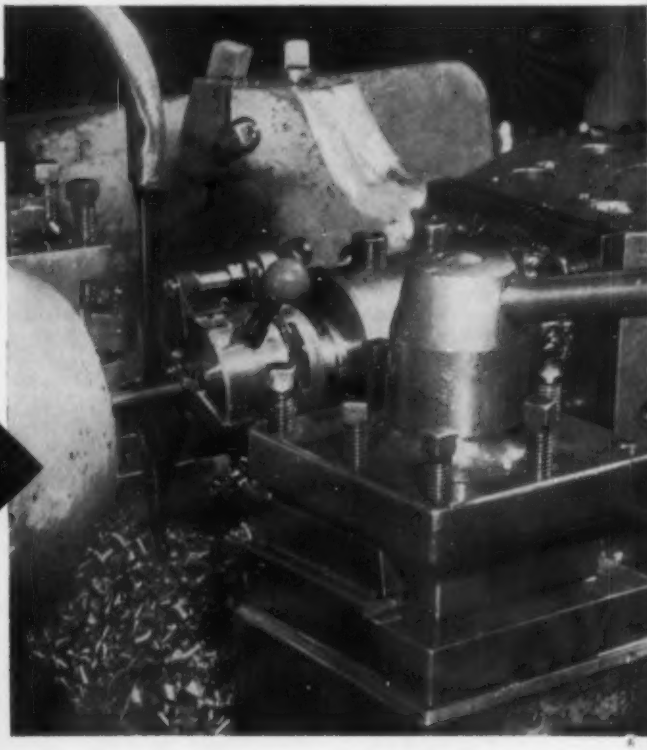
Bill

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS

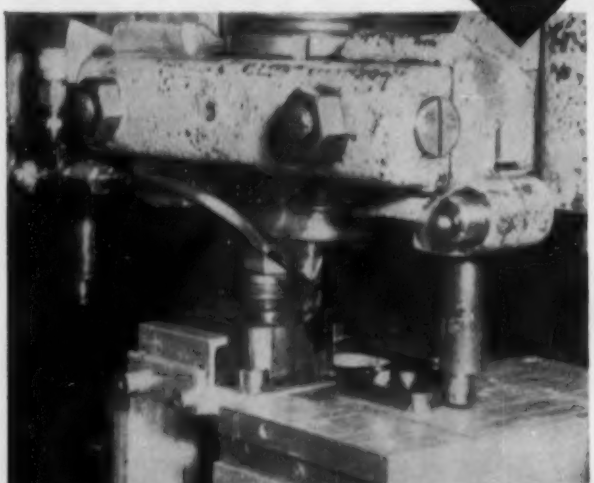
"We found the key to successful machining of ti-stainless--

GULF ELECTRO CUTTING OIL"

says Mr. D. E. Gillmor, Vice President of Gillmors, Inc., Long Island, N.Y.



Improved machining practice on ti-stainless quickly followed a switch to Gulf Electro Cutting Oil in this shop, with results like these: from 20 pieces per tool grind to as many as 45; and finish improved about 43 microns—from 63, the best obtainable with other cutting oils, to as low as 15. For additional information, see page 144 of the September 13, 1954 issue of American Machinist.



Gulf Oil Corporation · Gulf Refining Company

1822 GULF BUILDING, PITTSBURGH 30, PA.

Engineering Digest of New Products . . .

Quenching Oil

A new quenching oil with fast cooling rates in conventional quench setups has been announced by the Shell Oil Co. The oil's cooling rate is sufficiently high initially to avoid unwanted transformation products in low carbon or low alloy sheets, yet slow enough in the final stages to

control the dangers of warpage, cracking, or distortion. Other advantages claimed are high water tolerance and low volatility and drag-out losses. The oil drains off hardened parts easily and is generally compatible with heat treating salts and does not form any insoluble soaps when parts are quenched from salt baths. The flash point of 380° F. and the fire point of 425° F. of the new oil are high. Twist drills, taps, reamers, files, and other hand tools; punches and dies; flat and wound wire springs; lathe, planer, shaper, and milling machine tools; shafts, axles, and connecting rods are parts which may be hardened in the new quenching oil.

For further information circle No. 754 on literature request card, p. 32-B.

Vacuum Pump

A new high-vacuum diffusion pump for moderate sized vacuum systems has been announced by the Equipment Div. of National Research Corp. The pump is a 10-in. diameter fractionating diffusion pump which can also be used as a booster pump. When using Narcoil-40 pump fluid, the pump has a speed of 1700 liters per sec. in the pressure range from 5×10^{-4} to 5×10^{-6} millimeters of mercury and has a throughput of 3800 liters per second at 10 microns. It blanks-off below 1×10^{-6} mm Hg and has a maximum tolerable forepressure of 200 microns. It operates as a booster pump when Narcoil-10 is used as the pumping fluid. Pumping speed at 1 micron is 2000 liters per sec. and the pump has a throughput of 6000 liters per sec. at 10 microns. Blank-off is better than 1.5×10^{-4} mm. Hg and maximum tolerable forepressure is 400 microns.

For further information circle No. 755 on literature request card, p. 32-B.

Portable Pyrometer

The Fielden Instrument Div. has announced a surface pyrometer for measuring high temperatures of metals and refractories when they are surrounded by cooler air. According to the company, the instrument will give accurate temperature readings within 0.5%. It is suitable for measuring "spot" temperatures in a range from 100 to 2400° F. and may be used for oxidized steel or cast iron, many oxidized nonferrous metals, painted surfaces and others. The measuring head of the instrument is mounted on a telescopic arm, 9 ft. long. It is normally connected by a trailing lead to a portable millivolt

meter that is calibrated in temperature degrees. Readings from the pyrometer are obtained 5 sec. after the head is placed upon the hot body. Applied to the surface of a hot body, the instrument head, which is concave in shape, closes off a portion of the heated material, forming a uniform temperature enclosure. A reflector, created by a heavy gold plating inside the instrument head, reproduces the surface conditions of the hot material. "Black body" radiation trapped within this uniform temperature enclosure is then sampled through a small fluorite window which is transparent to most of the infrared spectrum and measured by a sensitive thermopile.

For further information circle No. 756 on literature request card, p. 32-B.

Vacuum Degassing

The Centrifugal Casting Machine Co. has announced a Model 400 vacuum degassing chamber for eliminating

gas in molten metal. It can accommodate up to 1000 lb. of molten metal and uses either metal in ladles or in crucibles. This vacuum degassing chamber can process metals at pressures below 200 microns, the actual minimum pressure depending upon the metal being processed. The unit is suited for the degassing of pure copper, which considerably increases the conductivity of the copper, and to fast degassing of aluminum.

For further information circle No. 757 on literature request card, p. 32-B.

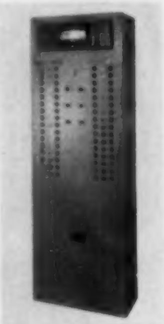
Cleaning Machine

Cincinnati Cleaning & Finishing Machinery Co. has announced a new machine which eliminates all hand labor costs and speeds cleaning of the large metal gondolas. The machine will clean 12 gondolas up to 60 by 44 by 32 in. in size per hour. The cleaning solution, heated by 70 lb. of steam, is sprayed at twice normal cleaning pressures to loosen the debris on the gondolas. The solution is

recirculated for reuse after dirt and scale are removed by a screen-type basket through which the solution must pass before being resprayed.
For further information circle No. 758 on literature request card, p. 32-B.

Control Center

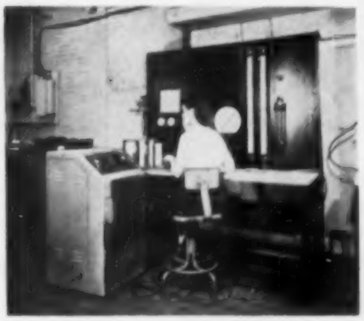
A control center to supplant the use of individual instruments for automatically checking multiple temperatures in process work has been announced by the Wheelco Instruments Div. The control center checks the temperature at each of the control stations in a fixed time interval (32 stations in 2 min.). A pilot light indicates the point being checked. Should any station be "off limits", visual and audible alarm is given. The amount of correction needed at any point is indicated. A manual reset switch clears alarm indication after temperature corrections have been made. A manual pulsing push button switch has also been incorporated in the control center to provide a means of manually checking any of the temperature points.



For further information circle No. 759 on literature request card, p. 32-B.

Leak Detector

A new mass spectrometer leak detector that will detect a leak rate of 5×10^{-10} standard cubic centimeters of air per second entering an evacuated system under atmospheric pressure has been announced by General Electric's Instrument Dept. It can be used selectively to locate a specific leak in the presence of other leaks, without loss of sensitivity. Twenty sensitivity ranges are provided by means of attenuating factors of 1, 3, 10, 50 and 150, and by four levels of emission current, making it possible to locate leaks of different sizes. A dual cold trap provides a large condensing area for removal of unwanted contaminants, and in most cases an external cold trap will not be required. The dual cold trap requires a minimum of cleaning, and the complete cleaning operation requires less than 20 min.



For further information circle No. 760 on literature request card, p. 32-B.

Testing Equipment

Ellis Associates has announced a bridge amplifier and meter for both dynamic and static work with SR-4 strain gages and similar resistance-type transducers. For static measurements the meter reads tension to the right and compression to the left of zero in the middle. The scales are arbitrary, with a simple system of calibration to make them read directly in terms of units being measured. For dynamic measurements, a d.c. cathode-ray oscilloscope is plugged directly into the front panel giving a d.c. signal with no microphonics, low intrinsic noise level as well as high sensitivity.

For further information circle No. 761 on literature request card, p. 32-B.

Sprayed Ceramics

Continental Coatings Corp. has announced a flame-spray ceramics process for coating metals. The spray coatings are applied by feeding powdered ceramic materials through a simple flame gun. These ceramics are sintered layers of refractory and chemically inert materials, such as aluminum oxide and zirconium oxide. Coatings resulting from the new process have high resistance to heat and chemical stability. Technique of application is similar to that required for the metallizing processes.
For further information circle No. 762 on literature request card, p. 32-B.

Microscope

Development of a new metallurgical microscope has been announced by the Bausch & Lomb Optical Co. New features include an oversized focusing stage with interchangeable stage plates, which adapt it quickly for work with either transparent or

The metal spars that support the rotor blades of the famed Piasecki "workhorse" are the modern version of masts on clipper ships . . . must stand great stress and strain.

To heat treat the Piasecki spars, the Metlab Company of Philadelphia uses a specially designed furnace, unusual techniques . . . and . . . Sun Quenching Oil Light.

For strength and flexibility . . .

20′ Piasecki Rotor Spars Quenched In Sun Quenching Oil Light

It takes real know-how to heat treat the 20 ft long tapered tubing used in Piasecki spars. At the Metlab Company of Philadelphia, Sun Quenching Oil Light plays a major role in the success of this job.

Sun Quenching Oil Light was originally selected by Metlab Company, after lengthy tests, because of its all around quenching ability, low cost and long life. For the Piasecki job, Sun Quenching Oil Light helps give the spars exactly the qualities they need . . . maximum strength with a minimum of distortion. *Proof once more of the ability of Sun Quenching Oil Light to satisfactorily perform difficult oil quench jobs.*

For information about how Sun Quenching Oil Light can perform for you . . . whether in a job shop or on a production line . . . see your Sun representative or write SUN OIL COMPANY, Philadelphia 3, Pa., Dept. MP-9.

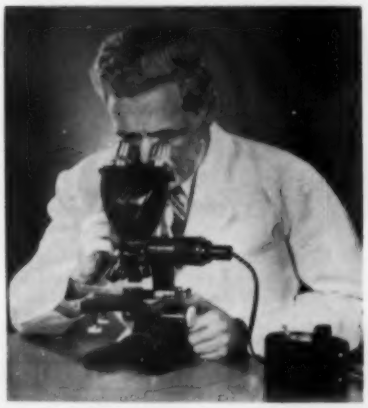
SUNOCO

INDUSTRIAL PRODUCTS DEPARTMENT

SUN OIL COMPANY PHILADELPHIA 3, PA.

IN CANADA: SUN OIL COMPANY LTD., TORONTO AND MONTREAL

opaque specimens; a fine-adjustment focusing knob located at table level to permit operators to work with their arms in a relaxed position, and an accessory lens for concentrating ex-



ternal illumination into the microscope for photomicrographic use. The instrument has new vertical illuminator and triple-revolving objective turret. Vertical illumination for the microscope is supplied through a true aperture diaphragm illuminator that provides uniform lighting.

For further information circle No. 763 on literature request card, p. 32-B.

Deburring Compound

A mildly acidic compound for barrel deburring, descaling, and derusting, has been announced by Oakite Products. The new material is designed to replace raw acids in barrel operations, where alkaline materials and abrasives are impractical because of time limitations. It is also designed to improve color of steel after alkaline deburring; to remove heat scale from steel; and to brighten brass, either with or without the use of abrasive media. It is recommended at concentrations of 1 to 3 oz. per gal. or it may be added in a dry form to the burnishing barrel.

For further information circle No. 764 on literature request card, p. 32-B.

Laboratory Furnace

The Harry W. Dietert Co. has announced a heavy duty, high-temperature furnace. This unit is designed for product research, quality control testing and small production items requiring high operating temperatures. Furnace may be designed for either horizontal or vertical mountings. Power ratings vary according to job specifications, length of element and maximum operating temperatures. Power is supplied to heating element by a special variable voltage trans-

former. Heating element has a 3 in. o.d., a 2 in. i.d. and is 1 to 60 in. long. Minimum temperature is 500° F. and maximum temperature, 2800° F.

For further information circle No. 765 on literature request card, p. 32-B.

Ultrasonics

A new line of stainless steel Sonicells which can be immersed in corrosive or conductive liquids has been announced by General Ultrasonics Co. These Sonicells are installed one to each square foot of tank side or bottom. For small scale production they are powered by electronic generators. Larger arrays are powered by motor-

alternator equipment. Units used in cleaning equipment will remove rust, oxide and scale in 10 to 90 sec. Interior surfaces and deep crevices are pickled or descaled at the same time. The Sonicells may also be used for electroplating and electroless plating by introducing ultrasonic vibrations into the plating bath. The vibrations and accompanying cavitation cause rapid replacement of the exhausted or saturated liquid layers surrounding anode and cathode, and increase plating density 2 to 100 times.

For further information circle No. 766 on literature request card, p. 32-B.

Vacuum Equipment

American Electro Metal Corp. has announced a line of Balzers high vacuum equipment to be exhibited at the National Metal Exhibition in Philadelphia, Oct. 17 to 21. Included will be a new micro fusion apparatus

for rapid determination of gas contents of metals and a high vacuum melting and casting furnace with a capacity of 22 lb. of steel. Similar furnaces are available with capacities of 55 to 440 lb.

For further information circle No. 767 on literature request card, p. 32-B.

Thickness Tester

A new nondestructive thickness tester has been announced by Unit Process Assemblies, Inc. The unit permits inspection of 100% of production, and will test thicknesses of metals deposited on metals, metals on nonconductors, and nonconductors on metals. The electronic unit is compact and portable, permitting use in almost any location. Thicknesses are read directly.

For further information circle No. 768 on literature request card, p. 32-B.

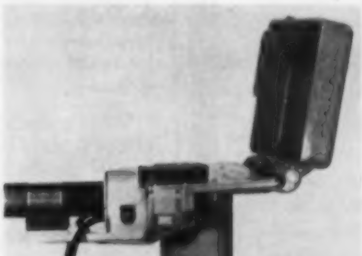
Demineralizer

The Penfield Manufacturing Co. has announced a completely automatic monocolumn demineralizer designed for users of 200 gal. per hr. high purity water. Raw water enters the demineralizing unit and passes only once through the column of mixed cation and anion resins. A flow meter enables setting water intake at an optimum rate for the most efficient ion exchange action and an electric purity meter plus automatic controls permits automatic control of the purity of the effluent.

For further information circle No. 769 on literature request card, p. 32-B.

Fluorescent Analysis

A new instrument designed for X-ray fluorescent analysis of large, slug specimens of steel or other metals, has been announced by the North American Philips Co. It handles metallic specimens ranging in depth from ⅜ to 1¼ in. and from 4 to 10 in. square in cross-section. The specimen is placed on a special platform and the operator lowers a metal cover to provide a ray-proof chamber. Closing and opening of the cover actuates a spring-loaded beam shutter which au-



tomatically transmits or cuts off X-rays from the specimen. It is used in conjunction with goniometers and X-ray tubes. The instrument for slug specimens embodies a 0.125-in. source collimator and a 0.005 in. receiving collimator and permits the goniometer to work in a range from zero to 146 deg. (two theta).

For further information circle No. 770 on literature request card, p. 32-B.

Controller

A new pneumatic recording controller for carbon potential has been announced by Surface Combustion Corp. The new pneumatic controller uses the dew point method of carbon potential determination. The unit in-

corporates all the features of the electronic automatic recording controller. The controller automatically compensates for any changes in work surface area as well as in gas analysis while the furnace is operating without manual adjustment.

For further information circle No. 771 on literature request card, p. 32-B.

Laboratory Balance

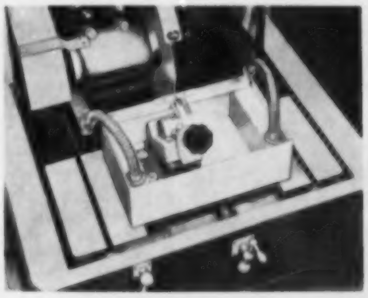
A new laboratory balance has been announced by the Torsion Balance Co. Torsion bands are made of Elgiloy, corrosion resistant alloy. A single beam with vernier permits weighings from 0.01 to 10 g. without the use of loose weights. The stainless steel calibrated beam assembly of the balance is placed over the torsion mechanism to minimize the effects of vibration. Capacity of the balance is

200 g., and the sensitivity reciprocal (the amount of weight required to change the rest position of the indicator one full scale division) is 0.02 g.

For further information circle No. 772 on literature request card, p. 32-B.

Sample Cutting

Buehler, Ltd., has announced a sub-jet cooling attachment and the "1000" cut-off machine for cutting metallurgical samples to size without burning or distorting the metal. This cooling attachment holds samples up



to 9½ in. long under water during cutting and at the same time applies jets of water directly to the cut-off wheel. The device fills and drains automatically, which permits loading and unloading samples in the vise out of the water.

For further information circle No. 773 on literature request card, p. 32-B.

Laboratory Filter

A new portable filter for use in the laboratory, small production shop or pilot plant, has been announced by Bart-Messing Corp. It has a capacity of 250 gal. per hr. and can be used with either the new annular element or a porous stone element, for either acid or alkaline solutions. The filter

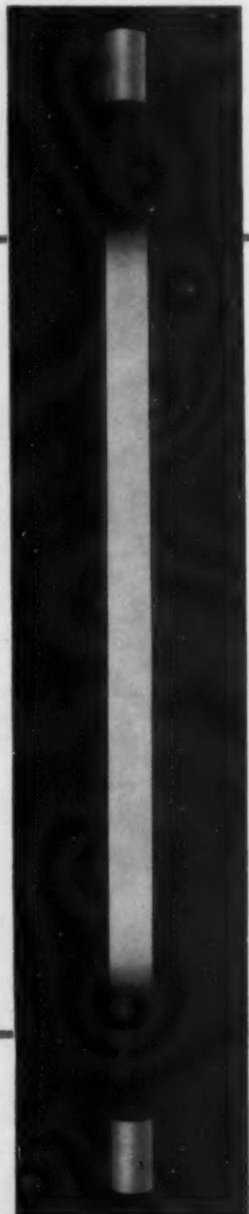
can be cleaned in 5 min. After the hand tightened tank cover is removed, the entire element lifts out so that it can be washed to remove sludge. It is furnished with stainless steel and rubber-lined components, or all iron parts.

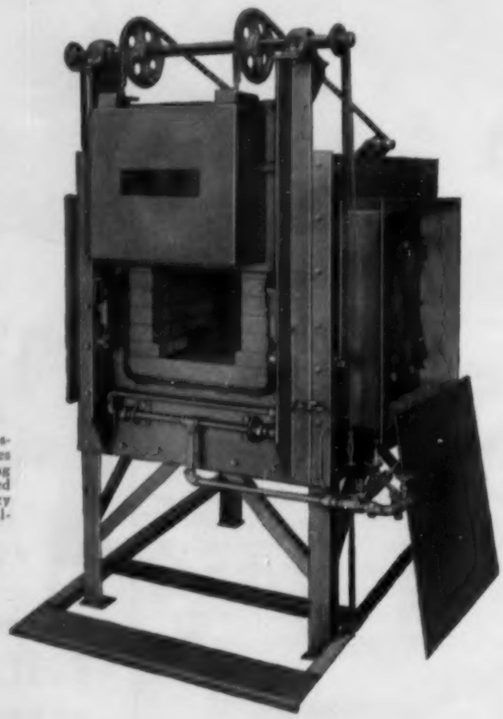
For further information circle No. 774 on literature request card, p. 32-B.

7 MORE REASONS WHY

HEVI DUTY *selects* GLOBAR® *Heating Elements* *for this* HEAT TREATING FURNACE

1. Uniform temperature in the work chamber.
2. Highest heat concentration...controllable in the chamber.
3. Clean radiant heat—furnace atmospheres controlled independently.
4. Widest range of temperatures—up to 2750° F.
5. Safer at all temperatures—no explosion or fire hazard.
6. Long, dependable performance during peak operations.
7. Minimum floor space needed, through compact, space-saving furnace design.





36 KW controlled atmosphere box furnace operates at 2500°F for heat treating high speed steel. Designed and built by Hevi Duty Electric Company, Milwaukee, Wisconsin.

PRODUCTION HEAT TREATING demands uniform high temperatures...for extended periods of time. That's one big reason why Hevi Duty and other leading electric furnace builders choose dependable, long-life GLOBAR® Heating Elements.

FOR OVERALL OPERATING ECONOMY it's hard to beat a well-designed industrial furnace equipped with GLOBAR Silicon Carbide elements...even when electricity costs more than other fuels. GLOBAR elements permit simplicity of furnace design and construction, give maximum concentration of heat, controllable in the chamber, with temperatures up to 2750°F. Furnaces are easier to operate—maintenance costs slashed to a minimum.

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What's New In Manufacturers Literature . . .

849. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment on nonferrous metals. *Allied Research Products*

850. Cleaners
Bulletins on di-phase cleaners, specifications, equipment, advantages. *Solventol*

851. Coatings
Data sheet on industrial Protectox, tarnish-resistant coating for silver, silver alloys, copper, brass and gold. *Technic*

852. Cold Finished Bars
Engineering bulletin, "New Economies in the Use of Steel Bars". *LaSalle Steel*

853. Cold Finished Steel
16-page booklet on 10 grades of cold finished steels. Analysis, machinability, heat treatment, wear resistance. *Jones & Laughlin*

815. Abrasive Cleaning
Catalog 54-W on brush types, sizes, speeds, filaments. Aids to power brush selection. *Pittsburgh Plate Glass, Brush Div.*

816. Abrasive Wheels
Operating suggestions and recommended wheels for finishing stainless. *Manhattan Rubber Div.*

817. Abrasives
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New 8-page manual on adhesive bonding. Materials, techniques, uses. *Rubber & Asbestos Corp.*

819. Alloy Castings
Data folders on two types of alloy steel castings. Composition, properties, hardenability bands, uses. *Unitcast*

820. Alloy Chart
Comparison of AISI, SAE, ACI, AMS, WAD and PWA chromium and chromium-nickel stainless specifications. *Cannon-Muskegon*

821. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

822. Alloy Steel
207-page book gives more than 50 complete case histories of alloy steel usage. *Climax Molybdenum*

823. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

824. Aluminum Sheet
New wall chart gives weight and bend data on aluminum sheet in standard alloys. *Kaiser Aluminum & Chemical*

825. Aluminum Cleaning
48-page booklet gives practical tips on materials and methods of cleaning aluminum and magnesium. *Oakite*

826. Aluminum Melting
Folder on electric furnaces for the aluminum alloy foundry. *Ajax Engineering*

827. Annealing Brass
8-page Bulletin S-1049 on high-speed annealing of brass strip for improved ductility. *Selas Corp.*

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Data on electrolytic copper plating anodes. *Lavin*

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Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

830. Atmosphere Furnace
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833. Beryllium Copper
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Folder on Vacu-blast room with waffle-patterned sand blast floor. *Vacu-Blast Co.*

836. Boron Additive
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837. Brass
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838. Brinell Machine
Data on semi-automatic Brinell testing machine. *Detroit Testing Machine*

839. Bronze
Folder gives tables of properties, uses, forms and other data on phosphor bronzes. *Chase Brass & Copper Co.*

840. Bronze Bearings
New brochure on bearing bronze. *American Smelting and Refining Co.*

841. Carbon Control
Technical report on instrument for control of carbon potential of furnace atmospheres. *Lindberg Eng'g.*

842. Carbon Control
Bulletin SC-168 on system for automatically controlling carbon potential in continuous and batch furnaces. *Surface Combustion Corp.*

843. Carbonitriding
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846. Casehardening
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848. Castings, Bronze
16-page booklet on sand and centrifugal castings. *American Non-Gran Bronze*

814. Silver Brazing
A section on design of brazed joints in this silver alloy brazing manual illustrates correct and incorrect methods and discusses stress distribution. Silver brazing procedures, cleaning operations before brazing, jigging,

fluxes, atmospheres and heating are also included in this 20-page booklet. Among the heating methods considered are torch, furnace, induction, resistance, dip, molten metal, molten chemical bath dip. *Air Reduction Sales Co.*

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ing machine works. History of continuous casting. *Scovill Mfg.*

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64-page book on free-cutting brass, copper and bronze. *Chase Brass*

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881. Filler Metal
New colored chart gives complete line of filler metals for welding, metal each is suited to, forms available and methods with which it is used. *Arcos Corp.*

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New 28-page bulletin R-34 on properties and characteristics of 5 kinds of firebrick. Typical applications. Tables of brick quantities for arches of different sizes and shapes. *Babcock & Wilcox, Refractories Div.*

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887. Foundry Practice
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Data on luminous wall forging furnaces. *A. F. Holden*

890. Furnaces
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Catalog on furnaces for tool room and general purpose heat treat. *Cooley*

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6-page folder on gas-fired, oil-fired and electric furnaces. Typical installations. *Electric Furnace*

893. Furnaces
Bulletin 435 on furnaces for tool room, experimental or small batch production. Gas, oil, electric. Muffle or direct heated. *W. S. Rockwell*

894. Furnaces
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895. Furnaces, Heat Treating
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Folder on salts for bright gold plating. Equipment needed. *Sel-Rex*

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20-page bulletin on models, applications and how to use superficial hardness testers. *Wilson Mechanical Instrument*

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Bulletin 3150-G on castings for heat, corrosion, abrasion resistance. *Duraloy*

923. High-Strength Steel
66-page catalog on Mayari®R steel. Applications which take advantage of its wear and corrosion resistance. *Bethlehem Steel*

924. High-Temperature Alloys
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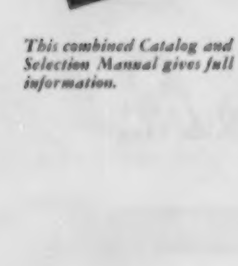

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Catalog of thickness gages, tensile testers, recorders, pressure gage testers, tachometers. *Amthor Testing Instrument Co.*

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32-page book on design and powder metallurgy for iron powders. Tables, graphs of properties. *Antara Products*

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Box furnace with cooling chamber for use to 3100° F. described in bulletin GEA-4713. *General Electric*

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Folder describes and illustrates tubular furnace for use in tensile testing, and control panels. *Marshall Products*

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8-page booklet on production of lead treated steels, their advantages and case histories of their use. *Copperweld Steel*

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Set of data sheets on lithium metal, lithium compounds. Uses of lithium in porcelain enamels, foundry, treatment of copper-base alloys. *Lithium Corp.*

943. Low-Carbon Stainless
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Literature on anti-seize molybdenum disulfide lubricant. *Bel-Ray*

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Catalog No. 460 on uses of colloidal graphite in industry. Table lists 40 basic dispersions of graphite. *Acheson Colloids*

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Reprint describes an investigation to evaluate inert-gas-shielded metal-arc welding of magnesium. *Air Reduction*

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20-page booklet, E-232, on Balphot all-purpose metallograph—bright field, dark field, polarized light, phase contrast. *Bausch & Lomb*

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200-page catalog of metallurgical apparatus: cutters, grinders, mounting presses, polishers, metallographs, microscopes, cameras, testing machines, analytical apparatus, spectrographs, furnaces, accessories and supplies. *Buehler, Ltd.*

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962. Microscopes
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977. Plating
12-page booklet, "Guide to Better Plating Power", describes selenium rectifiers for different plating applications. *Bart-Messing*

(Continued on p. 32A)

(Continued from page 31)

978. Plating Equipment
Bulletin on pencil for detectin
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995. Roll Formed Shapes
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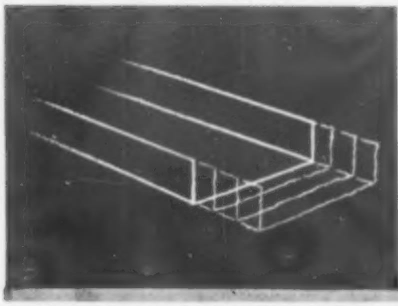

HOLCROFT and the SHAKER HEARTH FURNACE

Volume Production of SMALL PARTS

Controlled atmospheres—heating—fuel economies—stock handling. All these are factors to consider when you are trying to determine which heat treat furnace to select.

Take stock handling, for example. You might well consider a shaker hearth furnace if you are a volume producer of small parts such as screw machine production or stampings. It's continuous—a type of stock handling that's geared to production flow—and a type that eliminates the possibility of a bottleneck in the heat treat department.

The work is either manually or automatically placed directly on a hearth which is designed to move forward quickly a few inches, stop suddenly, and then return to its original position. The sudden jolt slides the parts through the furnace. An alternate arrangement is set up so that the hearth moves forward slowly, halts, then snaps back to its original position. Either method assures uniform heat treatment of each individual part.

You can get engineering information—honest appraisals of your problem—if you consult Holcroft when you are planning expansion. The result is bound to be a heat treat facility *balanced* to your production requirements. It will cost you less in the long run! Write today for complete information!

Holcroft & Company, 6545 Epworth Blvd., Detroit 10, Michigan.

PRODUCTION HEAT TREAT FURNACES FOR EVERY PURPOSE

CHICAGO, ILL. — CLEVELAND, OHIO — DARIEN, CONN.
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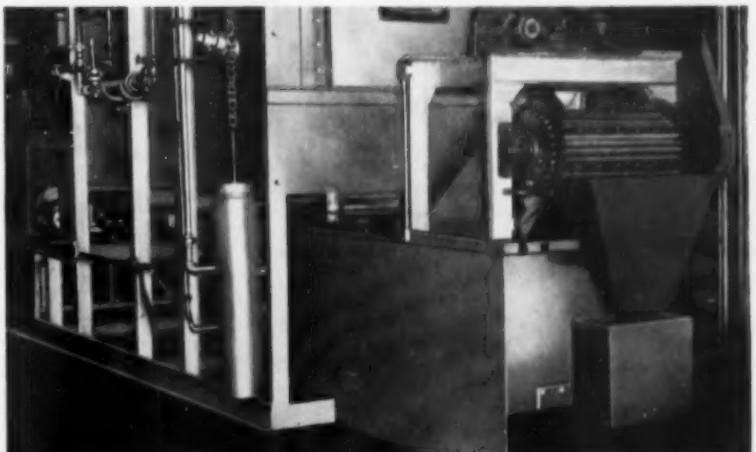

OYS

plications for 28 different grades of cast stainless steel. *Cooper Alloy Foundry*

1018. Stainless Steel
Bulletin shows plates, forgings, sheets, tank heads, flanges. *G. O. Carlson*

1019. Stainless Steel
Data card 178 on stress-rupture properties of chromium-nickel stainless steel weld deposits. *Babcock & Wilcox Co.*

1020. Steel 52100
New stock list on 52100 tubing, bars and ring forgings. *Peterson Steels*

1021. Steel 52100
Data sheet on high-purity 52100 steel, made by vacuum melting. *Vacuum Metals*

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New 38-page Catalog D-15 shows value of three-dimensional microscopes for industrial assembly lines and research laboratories. *Bausch & Lomb Optical*

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8-page bulletin on SR-4 universal testing machine of 60,000 lb. capacity. *Baldwin-Lima-Hamilton*

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1029. Thermocouple Data
42-page Bulletin TC-9 on thermocouples, radiation detectors, resistance bulbs, accessories. *Wheelco*

1030. Thermocouple Wire
Bulletin on thermocouple wire and thermocouple extension wire lists sizes, metals, insulations. *Claud S. Gordon*

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20-page Bulletin 714 on thermocouples, protecting tubes and wells, insulators, leads, connectors, heads. *Gen. Electric*

1032. Thickness Measurement
Data sheet 10.9-1a on sheet and coating thickness measurement on a continuous basis. *Minneapolis-Honeywell*

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New bulletin F-5609-3 on portable tin content indicators for solder. *Wheelco Instruments Div.*

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766	792	818	844	870	896	922	948	974	1000	1026	1052
767	793	819	845	871	897	923	949	975	1001	1027	1053
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773	799	825	851	877	903	929	955	981	1007	1033	
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777	803	829	855	881	907	933	959	985	1011	1037	
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And Other Specialty Alloys
Put into operation this year, Globe's new plant is the most modern in the country. Located at Beverly, Ohio, it is ideally situated for distribution of its diversified line of ferroalloy products by rail, water and truck. With five electric furnaces, Globe has a combined capacity of 32,000 KVA.
The company is staffed with highly competent and experienced operators, research and metallurgical engineers. They are available for consultation on any problem involving the use of ferroalloys.
May we discuss your needs with you?
Ferrosilicons—Made from high quality raw materials assuring a clean metal, free from segregation and inclusions. Plants at both Beverly and Jackson, O.
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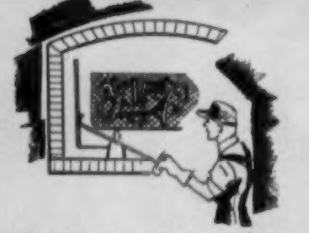
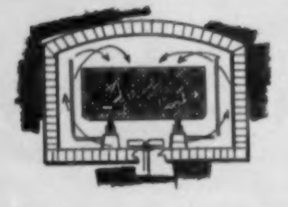
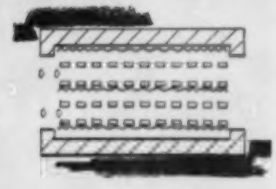


Safety! Extremely low voltage makes CORRTHERM elements completely safe. Let operator or work load bang it if they will. Neither element nor operator will be hurt.



CORRTHERM elements act as natural baffles to direct forced convection streams through the charge. The use of electric furnaces for carburizing and carbonitriding is now practical.



In continuous type furnaces CORRTHERM elements hang between lines of work as well as on side walls. Note how closer corrugations (at each end of element) compensate for incoming cold work and door losses.

NEVER BEFORE ANY ELECTRIC ELEMENT LIKE THIS NEW ONE BY LINDBERG

On the opposite page is a photograph of Lindberg's new CORRTHERM element for electric heat treating furnaces. You can see how radically advanced this element is over anything now used.

Wherever electricity is the preferable source of heat for metal treating the CORRTHERM element now makes its use practical, efficient and economical.

And this includes carburizing and carbonitriding furnaces, too! Problems created by the use of electricity in these types of furnaces are well known. CORRTHERM elements eliminate them completely. These facts tell you how and why:

LOW VOLTAGE: Operates at extremely low voltage. No leakage through carbon saturation. Around Lindberg we talk about it as the electric element "without any electricity...to speak of!"

ATMOSPHERE CIRCULATION: Elements act as baffles to direct circulation of convection streams.

SAFETY: Extremely low voltage also eliminates shock or short hazards.

DURABILITY: Watts density at all-time low. Element practically indestructible. Work load or operator's charging tool can't hurt it.

EASILY INSTALLED: Element is not enclosed, just hangs in furnace. No complicated mountings required.

CORRTHERM, Patent No. 2694740 (other patents pending), was developed in Lindberg laboratories, by Lindberg metallurgists and engineers. To find out just how its advantages can be applied to your heat treating processes get in touch with your Lindberg Field Representative. (See classified phone book.)

LINDBERG ENGINEERING COMPANY

2448 West Hubbard Street, Chicago 12, Illinois

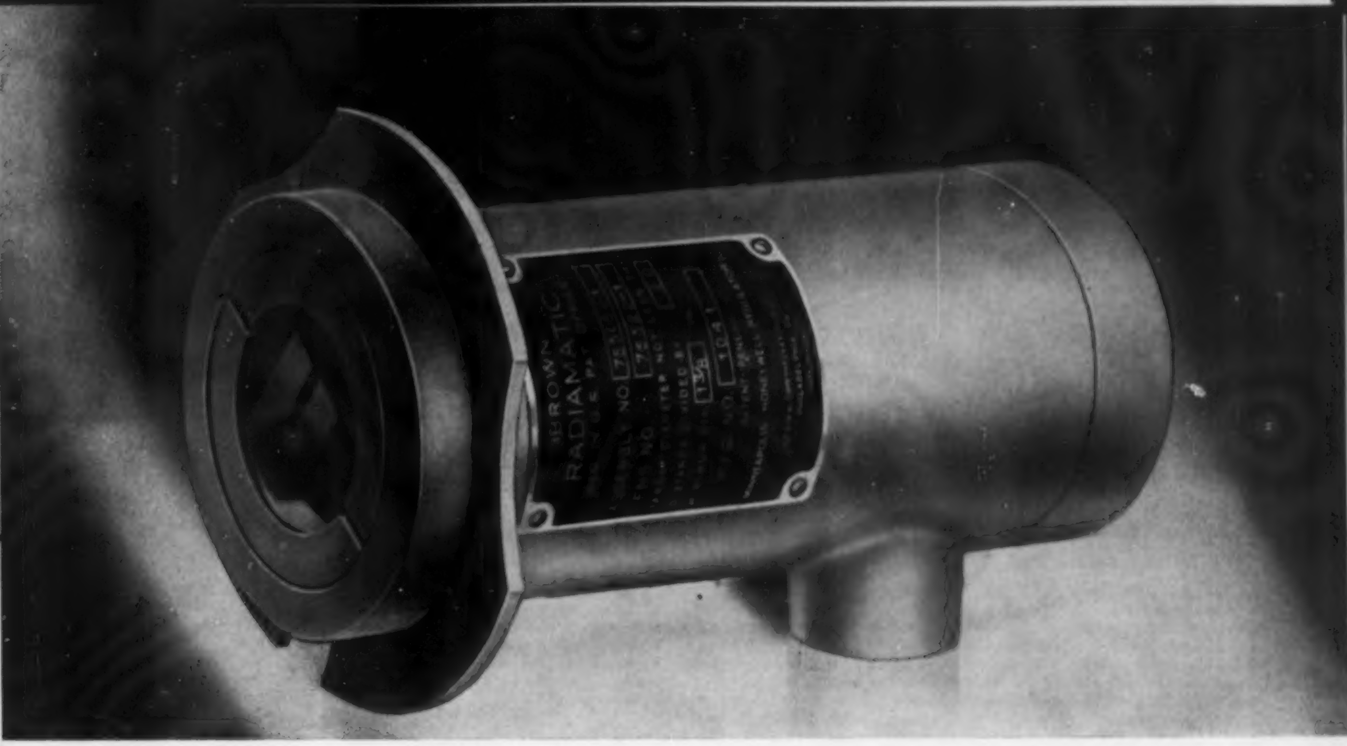
Los Angeles Plant: 11937 Regentview Ave., at Downey, California

If you are in Chicago during the period of the three shows, September 6 to 16, plan on attending one of the special showings of this new element at our plant. Just phone MOnroe 6-3443 and we'll make the arrangements.

No retort needed in pit-type carburizing furnace with CORRTHERM elements. Again see how elements serve as baffles to direct forced convection stream through charge.

CORRTHERM

by LINDBERG


BROWN
RADIAMATIC

in a Vacuum Furnace?

Vacuum furnaces *can* operate without the features shown below. However, we have learned — from building and operating more high vacuum furnaces than anyone else in the world — that these features more than pay for themselves in terms of safety, flexibility, time, trouble, and money. And these are just some of the special design improvements that NRC engineers can adapt to solve your special problems.

Our years of experience ensure that your NRC Vacuum Furnace will meet your needs as soon as it is installed — and will continue to do so year after year of low cost, trouble-free operation.

Use the coupon below to get your copy of the new NRC Vacuum Furnace catalog *just off the press!*

NRC
NARESCO
EQUIPMENT
CORPORATION

7 Mold turntable to permit the "split heat" alloy research technique or the casting of several ingots of varied size and shape from a single heat?

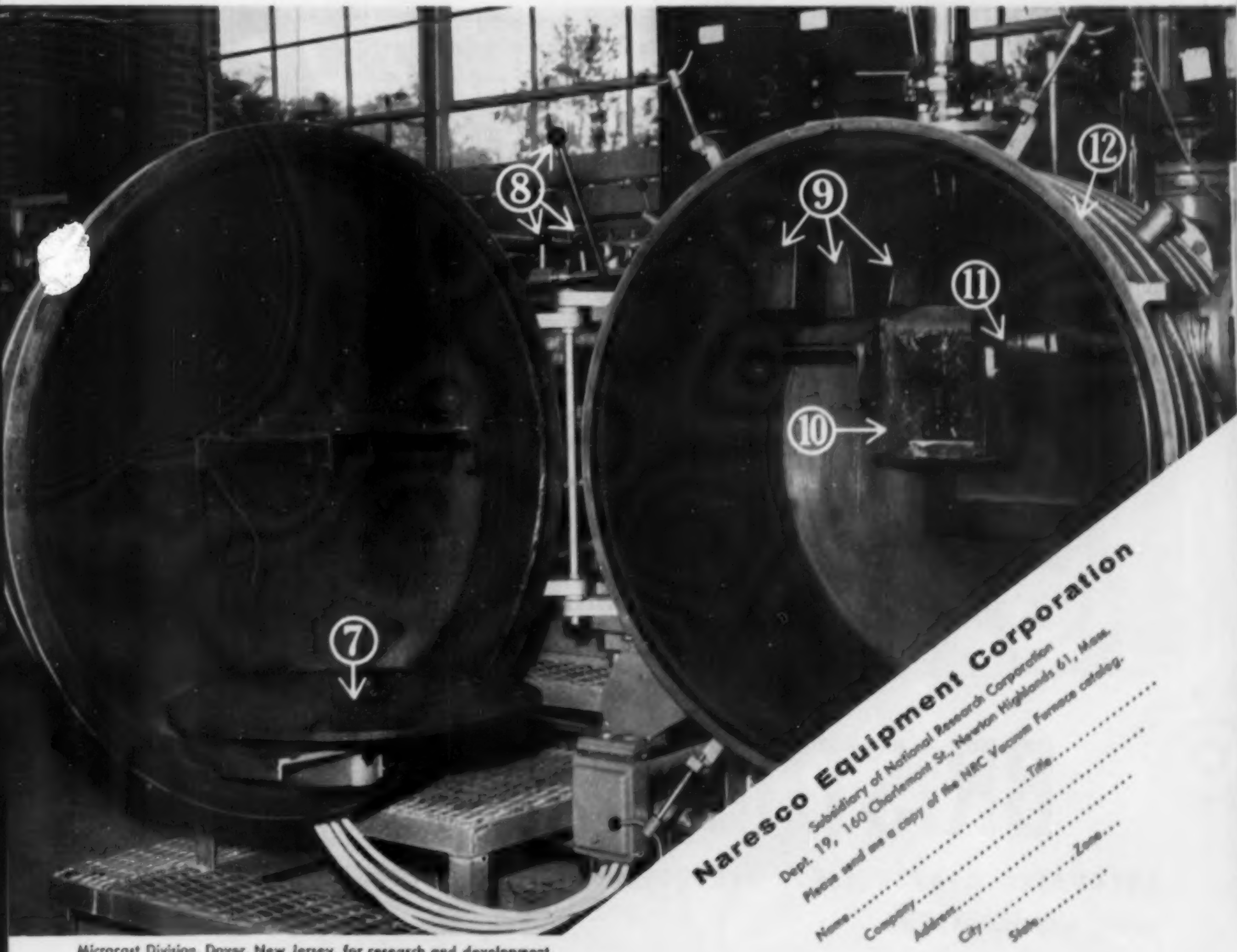
8 Conveniently located **controls** that allow one man to operate the furnace from a central position?

9 Bulk and alloy charging containers for using full crucible capacity and to allow late alloying additions for precise control?

10 Coil fully insulated electrically to eliminate arcing and resulting dangers of explosions from burn-through?

11 Fast, easy **coil disconnect** from coaxial feed-through to provide rapid, simple crucible change?

12 Large diameter, water cooled, **horizontal stainless steel tank**, for maximum accessibility, flexibility and ease of maintenance?



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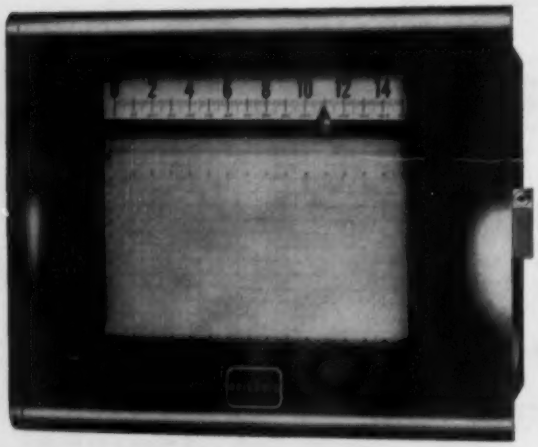
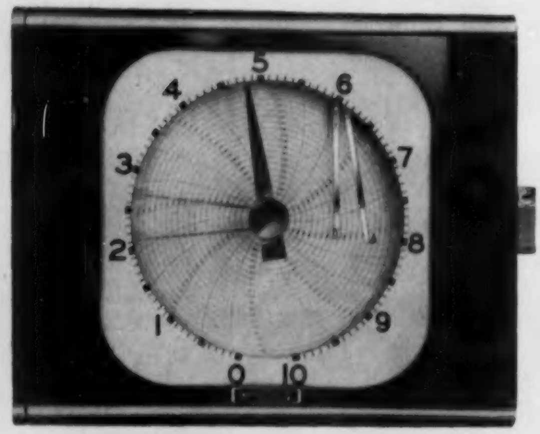
WHAT'S NEWS AT BRISTOL . . .



Three reasons temperature control is better with Bristol

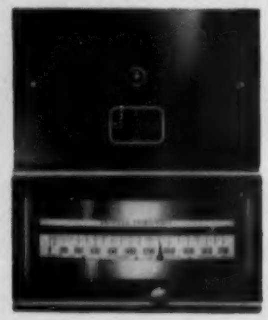


FIRST TWO REASONS are Bristol's Electronic Dynamaster Potentiometers with strip chart or round chart. Here's why:

No-Batt Continuous Standardization in these instruments eliminates need for dry cells. Result: No interruption in operation for standardization, no batteries to replace.

Recorders for every requirement — single-pen, two-pen, and multiple-record (up to 24 points)

Electric and pneumatic controllers for every furnace and oven control mode, including *electric controllers* for on-off, proportional-input, 3-position, proportional, proportional plus automatic reset, and time-program control; and *pneumatic controllers* for on-off, proportional, proportional plus reset, and proportional plus reset plus derivative control.



THIRD REASON: Bristol's Free-Vane® Electronic Pyrometer Controller. No relay chatter with this controller! Bristol's thyratron-operated relay puts a stop to that. Minute changes in temperature — less than 0.003" on scale — close or open the relay with positive trigger action. Available in thermocouple and radiation pyrometer controllers in ranges up to 4000F. New high-torque, rugged millivoltmeter gives greater accuracy and a sensitivity of 15 ohms per millivolt. Separate plug-in control units, variety of control modes available.

Get the whole story on these three rugged Bristol Furnace and Oven Controls. Write for free 48-page Bulletin P1260 today. It contains specifications, control diagrams and prices for every type of automatic heating control. The Bristol Company, 106 Bristol Road, Waterbury 20, Conn.

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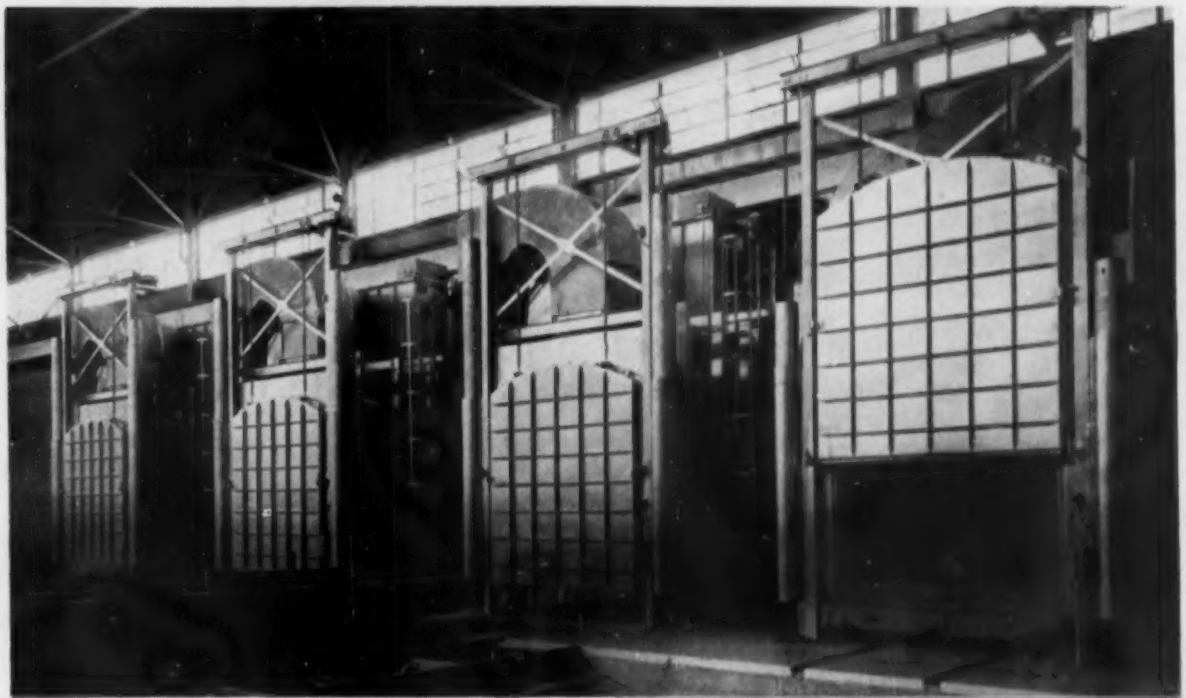
POINTS THE WAY IN BRISTOL'S *HUMAN-ENGINEERED INSTRUMENTATION*

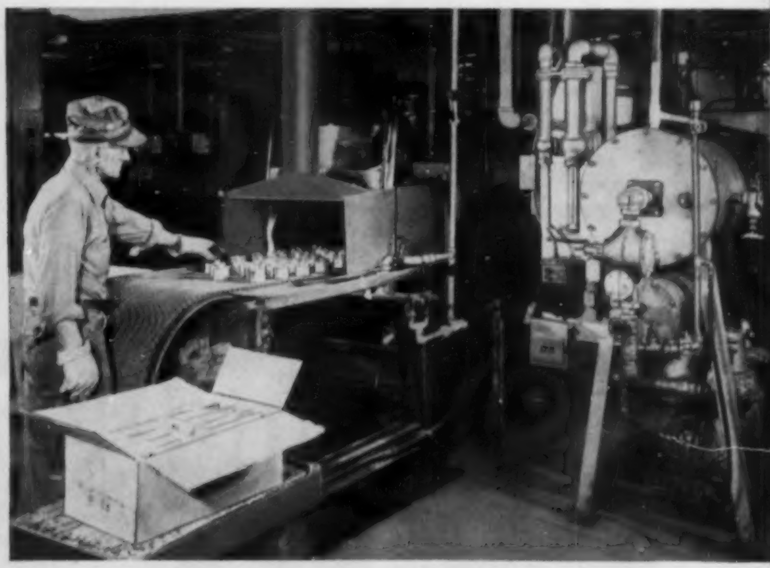
AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS



MODERN HEAT PROCESSING

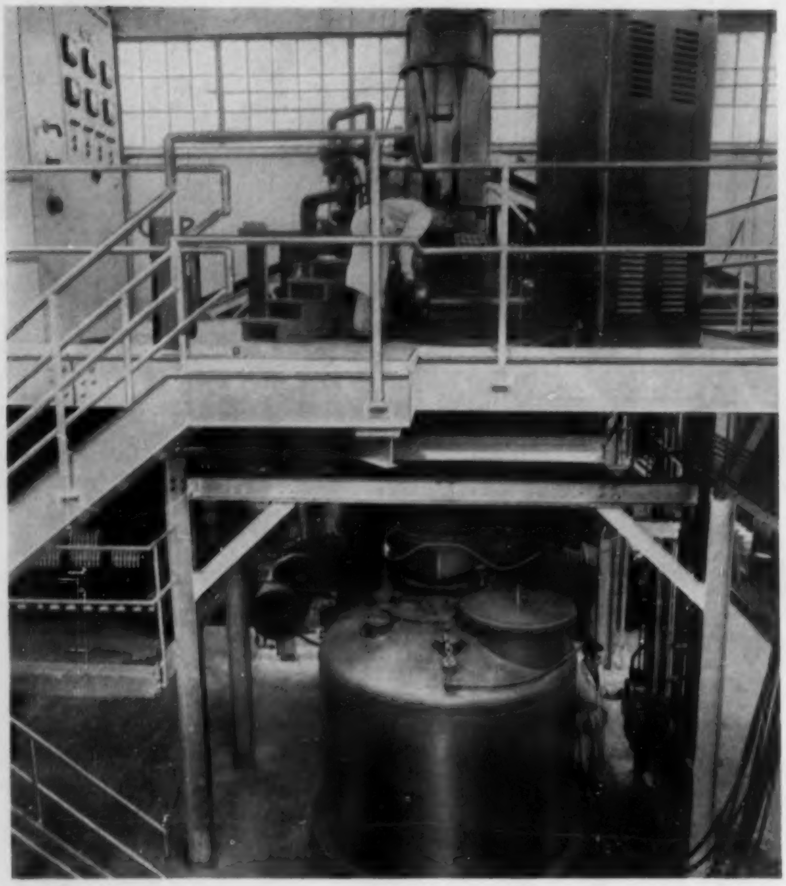
HUMP MESH-BELT G-E furnace is used by Salkover for high-production bright brazing, annealing, and atmosphere quenching of stainless steel. Elevated heating chamber helps prevent air infiltration, assures pure atmosphere.

G-E BOX-TYPE BRAZING FURNACE, is one of three used by Salkover Metal Processing for low-volume, high-quality copper brazing and annealing.



CLEAN PARTS EMERGING from Salkover's G-E mesh-belt furnaces are placed directly in shipping boxes. No need for pickling, grinding or polishing because protective atmosphere keeps parts free of scale.

The first semi-continuous,



1. Operation of the first semi-continuous, high-vacuum furnace. The furnace operator (upper deck) has reached the desired pressure and melted the charge. The melt's temperature is between 2800 and 3200° F.

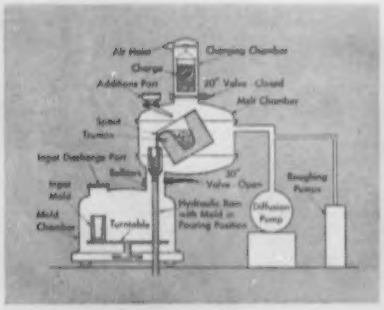
The operator is now swinging a chute out over his melt. Down this chute he will send alloying materials.

The next bulk charge rests in the interlock on top of the furnace. After he pours the melt and valves-off the mold chamber from the main furnace, the operator will introduce this second bulk charge to the crucible-coil assembly.

This is basically the operation of the Carboloy semi-continuous furnace. Valved interlocks allow repeated charging, melting, alloying, casting, and removal of ingot molds *without breaking vacuum.*

Notice the furnace's modular design which divides it into four sections—charging interlock (bulk and alloy additions), chamber cover (sampling, control, and inspection devices), furnace chamber (crucible-coil assembly, induction heating, and high capacity vacuum pumping), and chamber bottom (ram lift, mold table, and interlock).

The schematic drawing below shows these clearly and labels the parts discussed under the remaining pictures.



2. This drawing shows how an air hoist lowers the bulk charge to the crucible-coil assembly. Induction heating produces a homogeneous melt. High-vacuum pumping frees the melt of unwanted gases.

Alloying materials are introduced at the precise moment to produce the desired composition in the cast ingots.

A hydraulic ram lifts a mold to pour position and the ingot is cast. The ingot mold then returns to the turntable. It is indexed to a hot-topping position as the next mold moves to the ram-lift position.

3. A bulk charge swings into position over the charging interlock. The operator will lower the charge into the interlock. He then seals the interlock and exhausts it to equal the pressure in the furnace chamber. When this is accomplished, he opens the valve between the interlock and the furnace and lowers the charge to the crucible-coil assembly.

There are ports available for introducing power to pre-heat the charge before the interlock is opened to the furnace chamber. This accelerates production and reduces thermal shock to the coil-crucible assembly.

4. The operator uses a self-sealing sampler to pull slugs from the melt for analysis. All control and inspection devices focus on the operator, giving him continuous knowledge and control of the melt's progress.

Behind the operator is a central panel for the pumping and valve system. On its front is a flow diagram of the entire furnace with bright lights showing the status of the process at all times.

The furnace chamber contains such other equipment as a bridgebreaker, pyrometers, view windows.

high-vacuum furnace

Designed and built by

CONSOLIDATED VACUUM *for* CARBOLOY

CVC's modular design concept provides tremendous leeway in planning for future as well as present needs

The capacity and flexible design of this new CVC furnace call for careful evaluation of the role high vacuum can play in your company.

The furnace is now operating at the Carboloy Department of General Electric Company, Detroit, Michigan.

A high-vacuum, melting and casting furnace, it marks the solution to many problems which have bottlenecked the progress of vacuum metallurgy.

The first *semi-continuous* furnace, it melts charge after charge without breaking vacuum.

Its 1,000-pound crucible capacity gives a monthly yield of 120,000 pounds of high-purity metal.

Compact design and a system of remote controls make materials handling easier than ever before.

The world's fastest oil diffusion-ejector pump (CVC's type KS-16,000) evacuates 12.5 pounds of air an hour from the Carboloy furnace chamber.

CVC designed this furnace on the modular or "building block" principal. Initially, you can purchase the basic furnace module for batch operation with relatively small capital investment. Later, as production warrants, you can achieve full capacity, semi-continuous operation simply by adding the other modules.

As you read the story of the Carboloy operation, review your thinking on vacuum metallurgy. Consider its usefulness to your company as a profit maker. Then, permit us the opportunity of showing you how our advanced designs and manufacturing experience can produce for you an economical high-vacuum furnace.

• *A series of three CVC Information Memos on modular, high-vacuum furnace design is available on request.*

Consolidated Vacuum Corporation ROCHESTER 3, N. Y.

a subsidiary of CONSOLIDATED ENGINEERING CORPORATION, *Pasadena, California*

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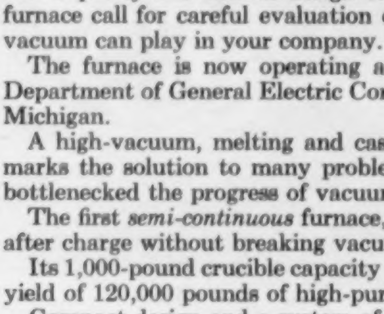
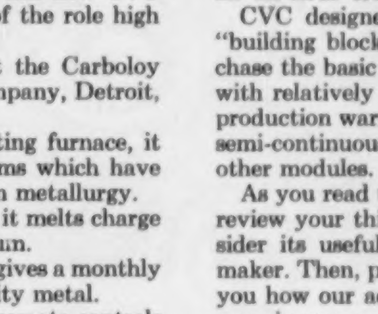


5. The 1,000-pound capacity induction crucible-coil assembly pivots on heavy-duty trunnions.

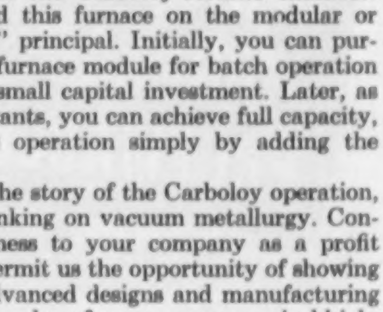
The mold lies in readiness some 15 feet below in the mold chamber. When the melt is ready to pour, a hydraulic ram thrusts the mold up under the crucible lip. The resulting short-pour distance from the crucible to the mold bottom produces high quality ingots.

At the completion of the pour, the mold chamber is valved off and removed from the furnace chamber.



6. The operator controls the melt's crusting action with a manual bridgebreaker. He observes the action through 6" sight windows (PYREX glass) located near his feet. He can remove the bridgebreaker without disturbing the furnace pressure.

To his left is an alloy additions interlock in which alloying materials are stored in small cans with drop-out bottoms. At exactly the right moment the operator adds these materials to the melt by means of a chute which sends them to the crucible.



7. The world's fastest pumping high-vacuum pump can hold the pressure in the furnace chamber below one micron. It's CVC's type KS-16,000 oil diffusion-ejector pump.

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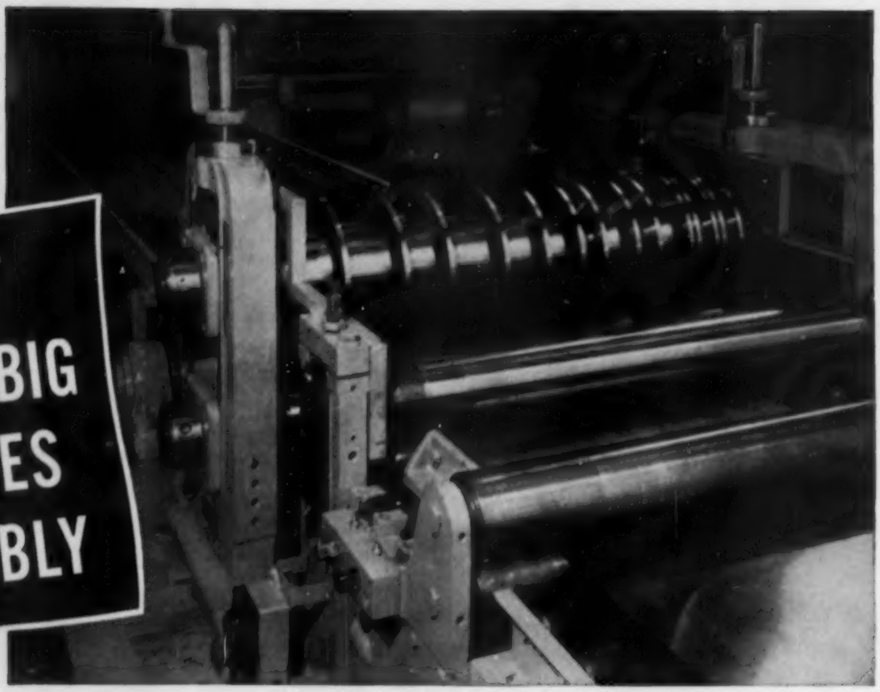

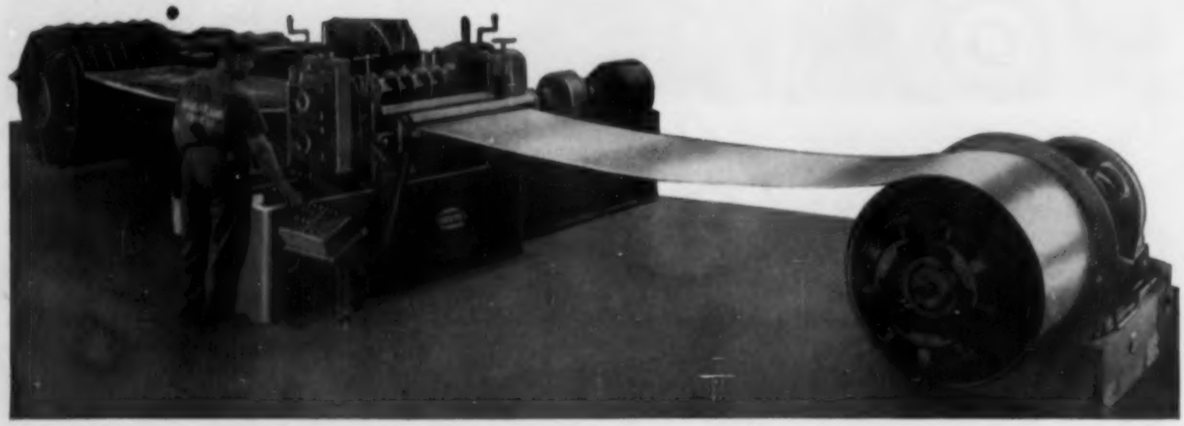


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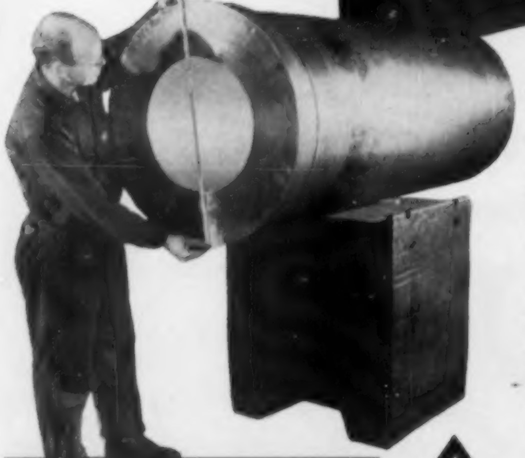

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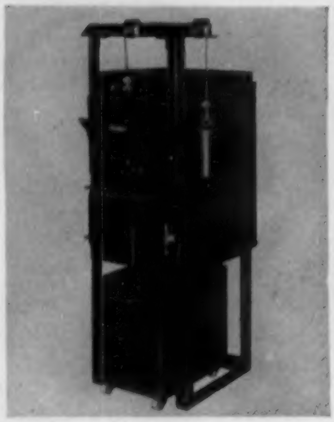

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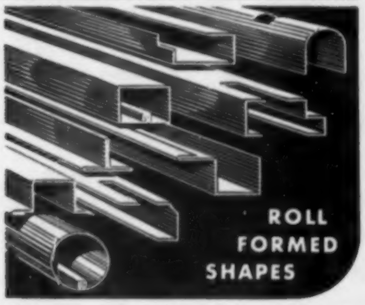

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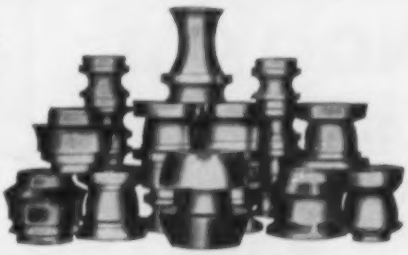

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Free, easy stock removal, good finish bright chip.	Rough out, poor finish dark chip, short tool life.	Easier stock removal than "C" but not as free as OLYMPIC FM, dark chip, short tool life.
DRILLING:- 5/8" DRILL, HAND FEED;		
Average drill pressure required, bright chip.	Maximum pressure required, slower feed, dark chip, very short tool life.	More pressure needed than for OLYMPIC FM, straw colored chip, fair tool life.
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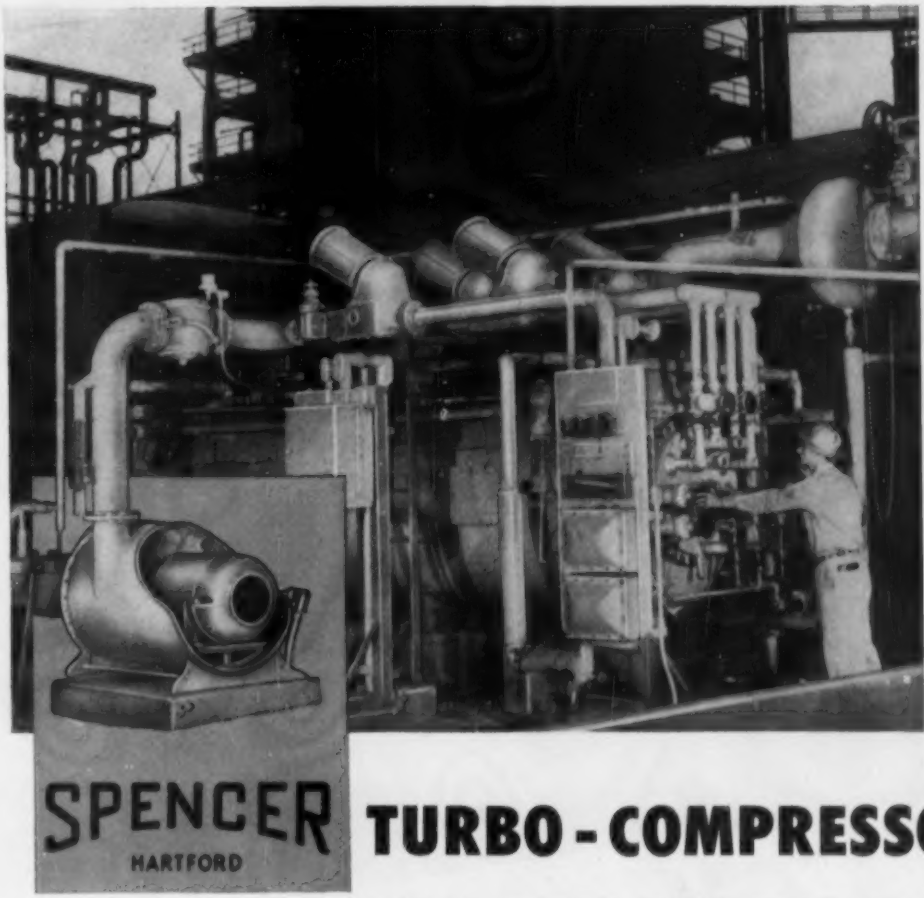

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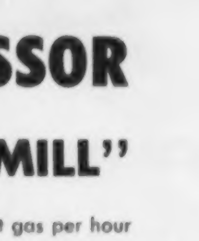

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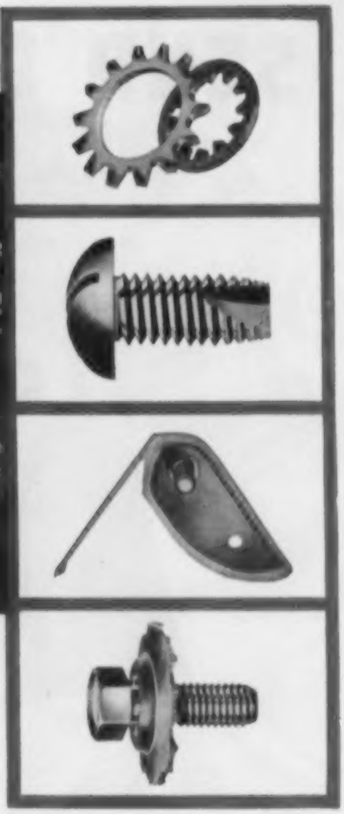

Heat-treating department at the Shakeproof Division of Illinois Tool Works, Elgin, Ill. A Nichrome muffle in one of these gas furnaces, operating at temperatures between 1500°F. and 1600°F., gave 36,732 hours of almost uninterrupted service between Sept., 1948 and April, 1954. Atmosphere consisted of ammonia and city gas.

In a rotary-type furnace in the same plant, a Nichrome retort operating at temperatures from 1600°F. to 1825°F., using ammonia and city gas, gave 17,248 hours of service.

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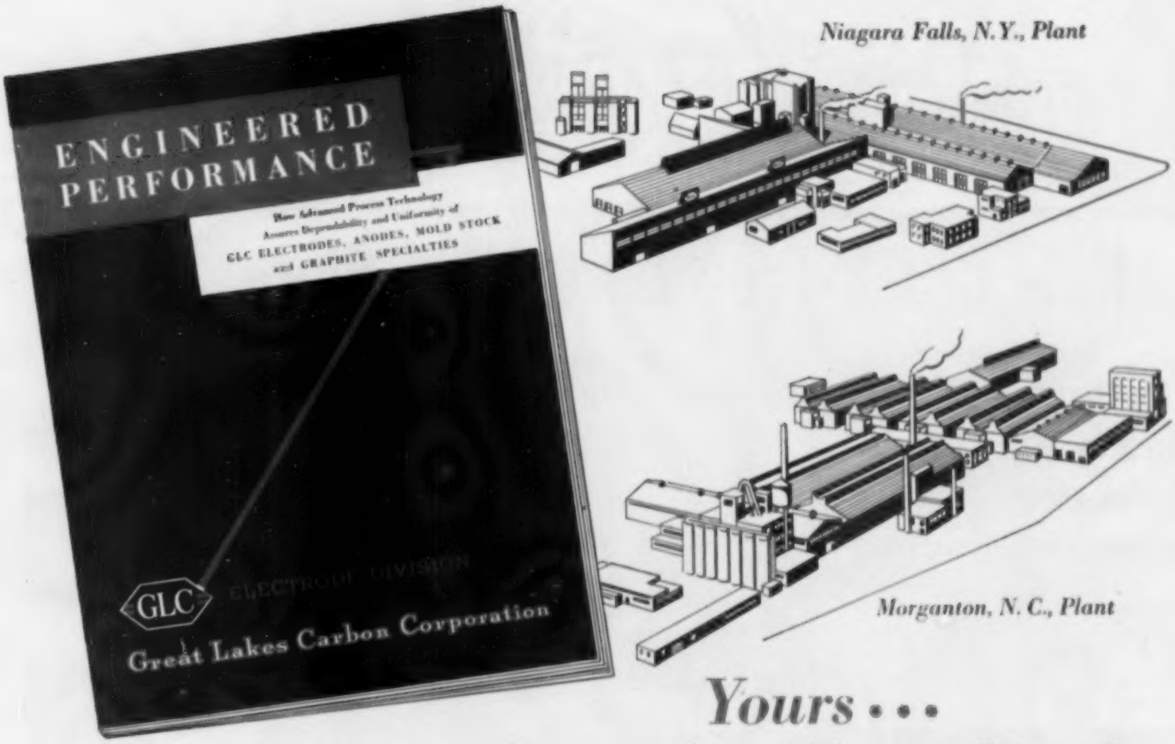
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New Crack-Free Chromium Plate gives superior protection

Structurally perfect finish from stress-free chromium

Differences in the structure of ordinary chromium and Crack-Free Chromium deposits are shown by the photomicrographs below.

Fig. 1

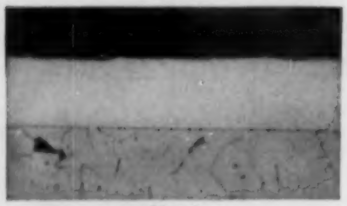

Fig. 2

Figure 1 shows a cross section of etched ordinary chromium .00125" thick, with part of its network of cracks. Note that some cracks extend through the deposit to the base metal, providing an unimpeded path for corrosives.

Figure 2 shows a section of etched Crack-Free Chromium also .00125" thick. Note the complete absence of cracks.

• • •

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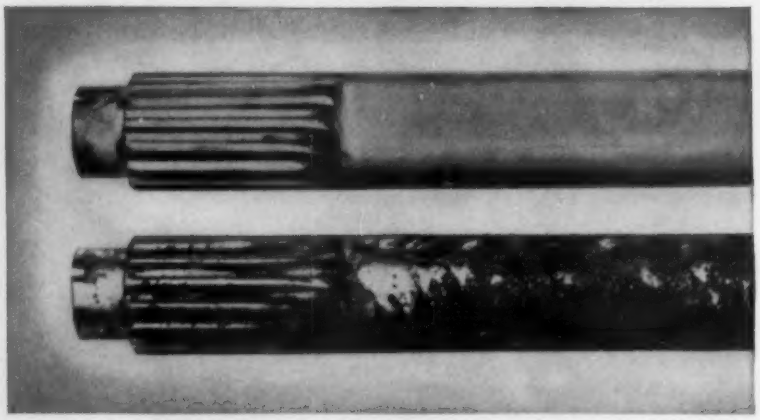

Upper steel shaft, with 0.0005 inch of Crack-Free Chromium, was virtually unaffected after 100-hour salt spray test. Surface of lower shaft with 0.0005 inch of ordinary chromium was completely covered with rust.

A basic need has at last been satisfied. A chromium deposit which gives better protection against corrosion is now obtainable by means of a new process developed by United Chromium.

Unichrome Crack-Free Chromium Plating produces more ductile deposits which are relatively free from internal stress. Thus, deposits do not crack as they are built up to hard plating thicknesses. In this respect they are unlike ordinary chromium which develops cracks, providing corrosives with paths to the underlying metal.

EFFECTIVE PROTECTION DIRECTLY ON STEEL

The photograph above shows that .0005" of Crack-Free Chromium plated directly on the steel prevented rusting of shafts subjected to 100 hours of salt spray, while the same thickness of ordinary chromium failed completely.

In other corrosion tests, parts plated with .0003" of Crack-Free Chromium were as good as new after a full year at 100% relative humidity and 110°F whereas parts with ordinary chromium were entirely covered with rust in days.

For many decorative applications, Unichrome Crack-Free Chromium can be plated directly on steel or zinc base die castings, eliminating need for scarce nickel.

OTHER BENEFICIAL PROPERTIES

Crack-Free Chromium deposits are hard (500 to 700 Knoop), have a low coefficient of friction, and a non-galling, non-seizing surface. The plate has superior ductility and resistance to thermal shock. Unusual leveling action is provided by the solution.

Its grayish, matte finish needs buffing for high luster, but this is done as readily as buffing dull nickel. Attractive two-tone effects can be produced by buffing some areas, leaving others as plated.

Unichrome Crack-Free Chromium has already proved its advantages for hard chromium plating and certain decorative applications in successful commercial operations. Bulletin CFC-1 gives more details. Send for your copy.

Announcing NEW RYCUT 50, *a leaded alloy*

fastest machining alloy steel in its carbon range

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The secret lies in the addition of a very small amount of lead (.15% to .35%) by a patented process. Finely dispersed, the lead acts as a lubricant between steel and cutting tool—giving greatly increased machinability without known effect on mechanical properties—the hardenability of New Rycut 50 compares with that of AISI 4150.

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FROM THE PRESIDENT TO THE MEMBERS

UNDER this rather formal title appeared a message in the September 1930 issue of Metal Progress signed by the late Robert G. Guthrie, then president of the American Society for Steel Treating. With this message came the announcement of a revised Society publication policy and the birth of the magazine Metal Progress. The magazine, along with other Society activities was, it said, to further the objects of the Society as outlined in Article II of the Constitution: "To promote the arts and sciences connected with either the manufacture or treatment of metals or both."

Metal Progress has clearly fulfilled the program laid out for it when Mr. Guthrie said "It will warrant your closest attention. It speaks for itself better than I can speak for it. I am sure that you will agree that the addition of Metal Progress with its enlarged editorial scope, its increased size, and its mechanical improvements without any increase in dues fulfills in great measure the desire of your Board of Directors to provide the members with the greatest possible service at a minimum of expense."

In the succeeding years Metal Progress has grown, as has your Society, now the American Society for Metals. While the staff of the magazine, capably led by E. E. Thum, editor since its first issue, will not blow the horns of success, I am proud to do it for them, speaking for the board of Trustees. Our National Secretary, William H. Eisenman, is enlarging on this theme in his biographical appreciation of the Editor. As to the magazine, there is no competitor in quality, styling, art, make-up, or editorial scope to Metal Progress. It stands alone in its field and combines with these skills a ready acceptance as the preferred advertising sales medium in the metal industry. May I acknowledge the support and cooperation of those firms whose advertising will appear in this, and future issues, as it has in the past.

The American Society for Metals is again at this time embarking on a broad program of further services to its membership. Let us look forward with confidence to the completion of this program in years to come, and trust its success will parallel and match that of Metal Progress in the past twenty-five. Happy birthday!

George A Roberts

President
American Society for Metals

The typographical format of this page, as well as the front cover, reproduces those of the first issue of Metal Progress

General View of American Metallurgy

By ZAY JEFFRIES*

The dean of American metallurgists believes that the law of self-preservation will keep atomic explosives in leash, that man will survive, and that our greatest future opportunities await us along that self-same road toward atomic energy. (A general)

ONE should not strain to try to describe American metallurgy as a separate entity. It is an integral but vital part of our whole economy. Without metals man would rapidly devolve toward stone-age conditions; without our modern industrial civilization metallurgy would be of no moment. That this intimate relationship should exist is not surprising because the two have evolved together in an ever-increasing complexity and richness in both the economy as a whole and metallurgy.

This complexity and richness are now increasing in a sort of geometrical progression – partly because of the earlier progress. Each new thing seems to have feed-back relations with all of the old ones, necessitating many changes in order to establish new balances. The complexity has been responsible for the development of metallurgy as a specialty, with all that this entails.

Although significant new developments in metallurgy have been forthcoming during recent decades and are, in fact, coming now at a fast pace, our concern should be, "Are we pulling our weight on the economic team?" We should not be complacent about past accomplishments nor about the present status. It is obvious to all metallurgists that as old problems are solved, an increased number of new ones appear. It is also common knowledge that the desires of designers can never be fully met. Metals and alloys have their limitations in properties and in cost. Also, metals fail in use. These things tend to keep the metallurgists humble.

However, writing as one metallurgist who has witnessed vast changes in his working life, I gain satisfaction in contemplating the progress in metallurgy. As compared with conditions in the early part of this century, the improvement is dramatic. The educational institutions are turning out more and better trained men; the advance in tools and techniques has been nothing short of revolutionary; the research laboratories have been greatly increased in number, size and competency; new elemental metals as well as a host of new and improved alloys have been forthcoming; works laboratories have taken a prominent place in advances, including production control; fabricating techniques have been created and improved; and metal societies and publications have reached new heights in excellence and service; metallurgists did and are doing their share in connection with national defense and development of atomic energy.

Metallurgists have proved themselves to be good citizens. No one need be disturbed about any fancied complacency of American metallurgists. Also we can be certain that, given what

*Past President and Honorary Member, American Society for Metals.

may be called "favorable economic climate", future progress will continue to accelerate.

So, in looking toward the future, it is not metallurgy that gives us concern but economic climate. In this area atomic energy looms large. In the ordinary course of new developments, we would have taken it more or less in stride as the discovery of a few more of nature's important laws. Of course, many of nature's forces and materials can be used destructively, but our civilization has been made possible by our ability to discover and *control* nature's laws so that the constructive rather than the destructive uses predominate.

Role of Atomic Energy

The atomic bomb came in wartime and was achieved as a war measure. Its introduction to the world at Hiroshima has had a marked influence on world psychology. Had these developments been made in peacetime, and had the first public use on a large scale been in connection with, say, power production, it is more than likely that the problem of utilizing atomic energy for constructive purposes and keeping it under control would have proceeded more normally. As it was (and partly because of so much secrecy) the postwar developments have taken on a rather awesome air. New fears have arisen with the hydrogen or fusion bomb. We hear much about survival. This is a new experience. Unless we can survive, it is futile to think of the future of metallurgy or of anything else.

Is it not clear that all this concern about survival is based, not on the control of atomic energy in peacetime in a peaceful world, but on the fact that Russia also has the bombs? There seems to be little confidence that the communists will refrain from using them under certain possible conditions. Our concern about survival, therefore, is not about atomic energy nor its control in a sane and peaceful world, but primarily about the communists. If that is true, we can stop worrying about the dangers of atomic energy as such and concentrate on the task of putting it to useful work. If we can do this, atomic energy will become so important that it will not be long before the economic structure of the whole world would suffer a violent dislocation if it suddenly became unavailable.

Survival in the Atomic Age

I do not wish to pose as a prophet but I have a firm conviction about atomic energy and human survival.

Whatever your concept of the term "survival" may be, the consequences of a large number of either atomic or H-bomb explosions seem too horrible to contemplate. This true statement does not get us very far, because horribleness, itself, seems no bar against war.

Yet if we could prevent future wars the fears about survival would disappear. This way out offers the best solution of the world's highest priority problem. We should vigorously explore every avenue which might lead to this much-desired objective and by all means we should *wage* peace. A study of history is not at all reassuring about the *prevention* of wars, so we cannot assume with complacence that there will be no more of them. Nor is being a decent nation insurance against aggression or its equivalent; Lithuania's principal crime seems to be that she was defenseless.

Consequently, we must face the future on the basis that, even with atomic and H-bombs available to both the communist and noncommunist groups, war is still a possibility. Assurance for survival in case of war lies, then, in the first law of animate life, namely, self-preservation.

When we used the atomic bomb against Japan, we did it to *end* a war, not to *start* one. We had little fear of retaliation of a nature that would destroy ourselves. We had an opportunity to use the atomic bomb as a weapon for aggression for five years after World War II and did not use it. We feared no retaliation in kind during that period. Does anyone believe that if Russia alone had had the atomic bomb during that five-year period, she would have refrained from using it if her demands had not been met?

Here we have one basic difference between the two worlds.

At present the use of atomic or H-bombs by either group will be countered by retaliation. There is no doubt that the ultimate consequences of such action could be devastating to both sides. In this fact lies safety. The law of self-preservation operates in each of the two opposing worlds.

This does not mean that there cannot be more big wars, nor that atomic energy will not be used if war comes. Each side will develop atomic energy to the limit of its ability, to use so as to damage the enemy with little or no damage to itself. The atomic-powered submarine is only one example. Hundreds of others will be forthcoming – in fact, some are already here – for use either in direct conflict or to protect the home front.

This means that nucleonics must be pushed

vigorously for both the military and industry, and I use "nucleonics" in a broad sense as meaning phenomena depending on the nucleus of the atom. Here is where America shines. The job must be done by national teamwork but American metallurgy, to do its part, faces the greatest responsibility in its history. Opportunity goes hand in hand with this responsibility.

In this work the government must become a real partner with appropriate nongovernmental units – somewhat as in the field of military aircraft, wherein the developmental and engineering costs of new models are entirely too large for private risk-capital. New laws had to be enacted, new agencies had to be created and a type of partnership unlike that in any other industry has been created between government and nongovernment units in a manner which provides security for the nation and opportunity for private enterprise. Can anyone doubt that our military strength in aviation is far superior to what it would have been without this helpful partnership?

In nucleonics new problems have faced us and will continue to confront us. We must work out this government-industry partnership in nucleonics in the best way for our common future. A good beginning has been made in the Atomic Energy Commission. That it has been subject to considerable criticism is not at all surprising; the surprising thing is that it has not been subjected to more and different kinds of criticism. The reason is that it has, on balance, done a magnificent job, steering a forward course aimed first at keeping our country secure, but their far-seeing eyes have also been focused on this good-partnership objective. Since new relationships will have to be worked out between private enterprise and government, we can't expect that all of the rules will be those in existence; new ones will surely be necessary.

A Hopeful Road Ahead

To sum up, my conviction is that we can face the future with little fear of extinction. We must remember, though, that neither horribleness of war methods nor decency of a nation will prevent war. Unless we can prevent war by waging peace and eliminate armament production (or reduce it to controlled proportions by performable agreements) we must consider that war is probable or at least possible. Even so, the law of self-preservation will operate for the warring units in such a manner as to insure survival. However, the warring countries will use atomic energy to the utmost, *short of nonsurvival,* the concern always being not with the survival of the enemy but of themselves. Power of retaliation in lethal nuclear weapons must therefore be developed along with general military strength. The possession of these weapons by those nations which are not hungry for power represents the safety factor.

In my opinion, therefore, the economic climate for the future of American metallurgy will be favorable. What an exciting outlook this is! Added to what now may be referred to as the rapidly growing orthodox metallurgy, there will be the metallurgy associated with nucleonics – again using the term to mean the properties of the atom's nucleus. People have hardly sensed its fantastic complexity and potentiality. At one extreme it embraces the largest and most costly processing plants in existence. It also deals with "particles" having only a fraction of the mass of an electron – nutrinos, for example.

We used to think of some 70 metals as the maximum among the 92 elements possible. That was before the days of isotopes. Now hundreds of varieties of these metallic elements are known, each with some characteristics different from all the others. Two of the isotopes of a formerly known element are uranium-235 and uranium-233, both fissionable. Of these, a little goes a long way. Also, there is a *new* element plutonium, made – actually manufactured – on an industrial scale. Who can now predict their usefulness as power producers any more than the men who made the first small buttons of aluminum only a few decades ago could foresee the world-wide industry of today?

We have witnessed merely the early beginnings of nucleonics. No one can now tell about the future of some of the nucleonic products. No one knows what new developments may lie ahead. No one knows what new human habits may result.

We do know that now American metallurgy is faced with a challenge greater than it has ever been confronted with before. We know that other groups constituting the nucleonics team have the same challenge. We know that when all of the members of this team perform to the maximum of their ability and energy, the forces for survival and continued progress will be enormous. God grant that they will be great enough to remove entirely the fear of human survival.

I believe they will. In the exciting adventure ahead, I have full confidence that American metallurgy will not be found wanting.

Steel Manufacture

*By WALTHER MATHESIUS**

A brief review of the three major steel-producing methods, with a look into a future when a widely decentralized steel industry may refine metal by the newer pneumatic processes and cast it continuously into extrusion billets or slabs for single mill stands. (D general, ST)

PRODUCTION of bessemer steel in the United States reached its all-time peak in 1906 with some 14,000,000 net tons of ingots. Viewed by itself this constitutes a remarkable accomplishment by a process that produced a mere 77,000 tons in 1870. Born in America as the "Kelly Pneumatic Process" at Wyandotte, Mich., in September 1864, it made the first "tonnage" steel we produced.

Production of openhearth steel exceeded bessemer for the first time in 1907. Since then the openhearth process has continued its march of progress as the mainstay of American steel production, and today it makes fully 87% of this country's 126 million net tons of total rated annual steel capacity.

The first heat of electric steel was produced in this country at Syracuse, N.Y. on April 5, 1906, by the Halcomb Steel Co. (now owned by Crucible Steel Co. of America) in the arc type of furnace invented in 1899 by Heroult in France. By 1930 the annual capacity of electric steel furnaces amounted to 2% of the country's total rated ingot capacity; for 1955, it constitutes 8.5%.

In the meantime production of bessemer steel has declined steadily since 1906, except for a single upsurge in 1949. Our present capacity of some 4.8 million net tons annually represents less than 4% of the country's total.

To be complete some mention should be made of the crucible process and the electric induction furnaces. Today, production of crucible steel has practically ceased. The induction furnace is limited to steels of special qualities – for instance the production of certain high-alloy steels by melting in vacuum or under various protective gases.

Looking to the future, we see a number of possible competitors to our standard steelmaking practices. These are the turbo-hearth developed experimentally in this country, the western European modifications of the basic bessemer process employing mixtures of pure oxygen and steam or carbon dioxide in lieu of air, and the oxygen-lance proceses recently commercialized at Linz and Donawitz in Austria.

In order to analyze our past developments intelligently and then, with no more than a calculated risk, attempt to predict future trends in steel manufacture, it seems appropriate first to define the objective of the steel industry and then evaluate our steelmaking processes according to their contribution toward this goal.

The writer's definition offered 20 years ago in *Metal Progress* for October 1935 can be considered equally valid today: "Steel quality is that group of properties essential to the constant production of finished goods of merit, measured in terms of satisfactory service rendered at the lowest ultimate cost. In this sense it is an ever-changing and a competitive standard." With this objective in mind, the following evaluations are presented.

Acid Bessemer Process in the U.S.

The decline of the bessemer process in this country, despite its substantially lower investment cost, is the combined result of a number of factors which adversely affect both cost and quality. Ores to produce low-phosphorus iron (yielding not more than 0.10% P in the steel) are becoming scarce and relatively expensive. The sulphur content of our metallurgical coals tends to increase, and thus low-sulphur pig iron required for the acid process becomes more expen-

*Consultant, Koppers Co., Inc., Chicago.

sive. Only small quantities of scrap can be ultilized in the converter, which usually means a higher cost of metallics per ton of steel. On the quality side, bessemer steel has higher nitrogen and phosphorus and therefore less ductility and a greater tendency to work hardening during cold deformation than openhearth steel. To be sure, these properties do offer definite advantages in certain applications, for instance in free-machining steels and in extra-hard tempered tin plate, but the decline in bessemer steel parallelled the replacement of hand mills for sheet and tin-plate production (which required a high phosphorus content to facilitate opening of sheet packs) by wide hot-rolled strip and cold-reduction mills, which preferred steels of high ductility and low work-hardening tendency. And since converter steel is outranked as to ductile properties for rails, plates and structural shapes, it does not seem likely that acid bessemer steel as we know it today will be able to compete with the basic openhearth and electric furnace processes in the years to come.

However, it is quite possible that acid converters will find increasing use in conjunction with the other two processes, especially in fully integrated steel plants charging a relatively high percentage of hot metal. By bessemer blowing, the silicon and part of the carbon can be removed from the hot metal prior to charging it into the steelmaking furnaces. This substantially increases the rate of production because of the higher temperature of the blown metal, elimination of charge ore and reduction of slag volume. This should result in lower fixed charges and yield substantial savings in fuel and operating and maintenance expense.

Another ray of hope stems from the recent decision by an American company to produce experimentally acid bessemer steel of low nitrogen content. Mixtures of oxygen and steam will replace the conventional air blast, using the technique developed recently in Europe. This offers the possibility of dephosphorizing the steel externally, utilizing a slag treatment which has been used successfully with acid bessemer steel for some time. Thus, there may be still a good future for low-nitrogen, low-phosphorus steel made by the acid bessemer process.

Openhearth Process

When the first American heat of basic openhearth steel was tapped at the Homestead Works of Carnegie, Phipps and Co. on March 28, 1888, the trail was blazed for the utilization of our country's vast ore resources of nonbessemer grade and for the economical recovery of the rapidly mounting accumulation of steel scrap which the bessemer process was unable to absorb. Since then the openhearth process has forged ahead steadily, assuming leadership in 1907 and continuing its growth to almost 109.4 million net tons annual ingot capacity for 1955.

Valid indeed are the reasons for its continuing success, despite the relatively large invested capital required and a fuel economy which at best leaves much to be desired. Among these reasons is, first of all, the ability to produce consistently high-quality steels throughout the full range of carbon specifications and numerous alloy steel grades from a widely varying proportion of scrap versus pig iron or hot metal. With the almost universal adoption of "driven" fuels (liquid tar or oil, with or without a high heat-value gas such as natural gas or coke-oven gas) and with the continuing trend toward larger furnaces, there has been a steady gain in production rate – tons of steel per furnace operating hour. Better scrap preparation and transportation facilities, more adequate charging and auxiliary equipment, and instrumentation for controlling the fuel and air ratio, furnace pressure and stack draft, for firing rates, and regulation of temperature of flame, roof, bath, checker chamber and air preheat – all these have contributed to higher output and a correspondingly lower number of man-hours required per ton of ingots.

It seems pertinent in this connection to call attention to the advantages in quality control and its cost which naturally result from larger heats. With the "heat lot" generally accepted as the unit for quality control of process as well as product, the cost of sampling, testing, analyzing, recording and reporting becomes obviously less per ton as the size of the heat lot is increased.

In summary, the large, modern basic openhearth furnace offers so many advantages and is burdened by so few handicaps that it will doubtless remain the mainstay of American tonnage steel production for many years to come. It has by no means reached its ultimate development. There is, for instance, oxygen-enriched air to increase flame intensity, heat transfer rates and melting speed; basic refractories for furnace roofs and other vulnerable furnace parts which limit the allowable flame temperatures; oxygen lancing to speed decarbonization, especially in steels of less than 0.20% carbon. All these, together with techniques to eliminate furnace delays, extend furnace life and reduce down-time

for repairs and rebuilding, are constantly increasing production rates and lowering costs.

Electric Steel Furnaces

At the time the Heroult furnace was introduced in this country in 1906, it was considered primarily as an improvement over the crucible process for a limited range of high-cost special steels for tools, dies, watch springs and cutlery. During the past 30 years, however, the process has expanded until it commands, virtually without competition, the rapidly growing field of stainless and heat resisting steels, and has become a major factor in the development of the so-called structural alloy steels.

As experience was gained and cost of electric energy decreased, larger furnaces were made, until today units of 70 to 90 tons heat capacity are producing a wide range of tonnage steels (especially where scrap is abundantly available). In nonintegrated plants using a cold charge (scrap), electric furnaces are definitely out-performing the openhearth.

Large ones are also beginning to compete with the openhearth by charging substantial proportions of pre-refined hot metal with scrap. While bessemer-blown hot metal has been used for this purpose for more than 30 years without gaining much popularity, a recent installation near Detroit, which combines a Linz-Donawitz type of oxygen-lance converter and 200-ton electric furnaces, shows promise. Aided by modern furnace improvements, such as top charging and induction stirring, such installations are expected to achieve hourly production rates substantially higher than openhearths and to require a lower investment of capital per ton of output. Thus, the electric furnace process seems well assured of continued progress in the U.S.

Modern Pneumatic Processes

The turbo-hearth process, employing the conventional Tropenas side-blowing technique in basic-lined converters, is in the pilot-plant stage in this country. Its objective is the rapid production of steels low in carbon, phosphorus and nitrogen, from hot metal charges of basic iron containing considerably less phosphorus than the 1.8% minimum required for the basic bessemer process. The relative economics cannot be evaluated until further experience has been gained with various operating problems. One of these is a satisfactory refractory lining, especially for the large vessels probably required for high production rates.

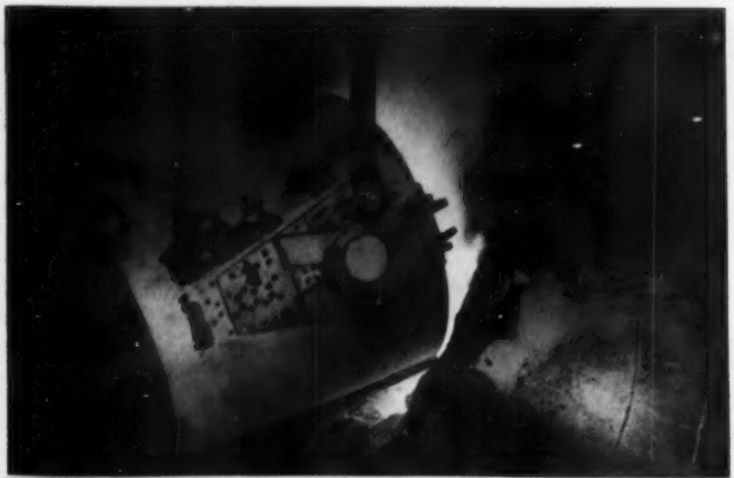
As those who have read *Metal Progress's* previous international reviews of metallurgy will know, intensive research and development is going on in Europe to improve the quality of the basic bessemer (Thomas) steel. Because of its higher phosphorus (0.06% max.) and nitrogen (0.02% max.) such steel lacks the ductility and workability required for modern cold strip rolling and deep drawing.

Continental Europeans cannot afford to rely on their limited openhearth capacity nor could they afford to abandon their Thomas converters and replace them by openhearth furnaces. So they set to work to produce Thomas steel comparable to openhearth in phosphorus (0.035% max.) and nitrogen (0.005% max.) and in the related ductility properties. For this purpose nearly every major plant has installed equipment for producing high-purity oxygen. Its application ranges from the mere raising of the oxygen percentage in the air blast, to the use of mixtures of oxygen with carbon dioxide or the use of superheated steam.

Many continental steelmakers are now confident that they can, by such means, meet the rising demand for wide, light-gage sheet and strip without having to abandon their basic bessemer facilities. Nevertheless, there are at least four new plants with openhearths of 150 tons or greater heat capacity in construction in Europe.

An interesting byproduct has been finding it feasible to produce steel from iron with only a fraction of the previous minimum of 1.8% phosphorus. This accomplishment (which in a way parallels the objective of the American turbo-hearth process) promises to the continental steelmakers a wider choice of iron ores. Against this they must of course debit a lower sale of high-phosphorus slag for fertilizer.

Differing rather distinctly is the recently developed oxygen-steel process which was first brought to full-scale production at the Linz and the Donawitz Steel Works in Austria and consequently dubbed the L-D process. This uses closed-bottom basic-lined vessels, and an inverted vertical oxygen lance directs a high-pressure jet of high-purity oxygen against the surface of the bath. The metal is rapidly converted to steel at high temperature under a basic slag with nearly theoretical consumption of oxygen. From iron of the usual basic grades (0.12 to 0.25% P) steel can be made of low carbon, nitrogen and phosphorus content with ductility comparable to the corresponding openhearth steels. Heat surplus is sufficient for 15 to 30% of scrap. Sulphur



Three Ingredients of Top-Blown Steel as Produced at Dominion Foundries & Steel, Ltd. of Hamilton, Ont. Top — Hot metal; center — oxygen; bottom — scrap

content of the hot metal can be reduced about one third. In a plant making 40-ton heats blowing time is about 22 min., giving a production rate which exceeds that of our modern large openhearth furnaces.

A noteworthy feature of the L-D process is that invested capital (including the oxygen-generating plant) is reportedly not more than half of that needed for a modern openhearth plant of equal capacity. It appears primarily suited for low-carbon grades; also it cannot utilize more than the amount of "home" scrap normally generated. Nevertheless, it promises to compete in cost and quality with the openhearth process in an important product sector, especially in areas where market scrap is scarce and hot metal is the principal source of metallics. With the aid of secondary processing (for instance, in large elec-

tric furnaces), oxygen steel may even compete with openhearth and electric throughout the full range of carbon and alloy steel specifications.

On the American continent, two oxygen steel plants have gone into production within the past 12 months. In one, at Hamilton, Ont., the steel is teemed directly into bottom-poured slab ingots, which are converted into wide strip for sheet and tin-plate products. The other plant, at Trenton, Mich., has installed 200-ton electric arc furnaces and will probably provide a wider range of products. Both of these plants have succeeded in overcoming a difficulty that besets their European prototypes – namely air pollution – through effective fume control and waste-gas cleaning facilities.

Steel Conversion

Numerous improvements and refinements have been made during the past quarter-century in the processes of hot rolling, hot forging, cold drawing and cold shaping of steel. Production costs have been lowered, product quality enhanced, production rates raised and dimensional and physical tolerances refined. However, few basic modifications in principles have been involved; many facilities built 50 years ago are still in effective service. The outstanding exception is the production of wide, light-gage, flat rolled steel, such as sheet and tin plate.

The major revolution in this field began in 1923, when ten years of diligent and ingenious experimentation by John B. Tytus led to the successful operation of the first continuous, wide, hot strip mill (36 in. wide in 30-ft. lengths) at Ashland, Ky. A parallel development by A. J. Townsend and H. M. Naugle was based on a mill they designed and built in 1916 at Massillon, Ohio, for the production of strip up to 24 in. wide. In 1926 they were able to produce hot rolled strip up to 36 in. wide in long coils, on a mill of their own design and construction at Butler, Pa. These pioneers blazed the trail for our modern hot strip mills which have replaced the old hand and pack mills almost entirely.

Thirty continuous, hot strip mills were completed in the United States alone by 1948, and many more have been added since, both here and abroad. Such mills can deliver strip from 24 to 96 in. in width for hot coiling in lengths of 2000 ft. at speeds up to 2300 ft. per min. Individual mills have set records exceeding 250,000 net tons per month. American wide strip mills account for a fair half of the country's entire steel production!

Similarly, cold reduction mills have taken their place alongside. First were the single-stand four-high reversing mills and single-stand temper mills; these were soon overtaken by 3, 4 and 5-stand tandem four-high cold reduction giants and, for the lightest gages, such as tin plate, the two-stand tandem temper mills. Along with these came continuous methods of annealing, electrolytic tin plating and galvanizing.

A vast and still growing market has thus been supplied with steel of better quality and higher dimensional precision. No doubt, this development represents one of the largest contributions made in our lifetime by the steel industry to the American standard of living.

This report should note several promising developments of recent date, such as the continuous casting of semi-finished shapes – blooms, billets and slabs in at least three places in the U.S. and Canada. Also the Sendzimir planetary hot strip mill, designed to reduce hot slabs to finished strip in a single mill stand. Substantially farther along on the road to economic maturity are the Sendzimir cold reduction mills, particularly suited for steels such as the austenitic stainless with its tendency toward work hardening.

Finally from France has come the Ugine-Séjournet hot extrusion process, using fiberglass as a lubricant, for converting billets into finished profiles or tubular shapes either too intricate for high-tonnage mills or of alloys having narrow hot working range.

There are those men of vision who can foresee a much wider field of usefulness for these newcomers in a widely decentralized steel industry. A self-contained steel plant might comprise facilities for gaseous reduction of high-grade concentrate pellets charged together with scrap and directly converted into steel in electric furnaces; a continuous casting department and Sendzimir mills and Ugine-Séjournet extrusion presses for converting the resultant semifinished shapes into a wide variety of finished products. Or, proceeding along other lines, we may be able some day to dispense entirely with steel melting as we now know it, and produce a wide range of finished products by the techniques of powder metallurgy.

Whether or not these dreams come true, we can predict with confidence, based on the proven ability of our research, engineering and management talent, that our steel industry will continue to advance, creditably cope with the problems of raw materials, processes and costs, and adequately serve our country's economy.

Metallurgy in Nuclear Energy

*By D. W. LILLIE**

Elucidation of uranium metallurgy leads the list of spectacular metallurgical achievements in the nuclear energy field; others have to do with zirconium, beryllium, graphite and other fuel materials, and the problems arising from radiation damage. (T25, U, Zn, Be)

SELDOM, if ever, has a completely new field of scientific endeavor grown as fast as nuclear energy, and certainly never has the scientific growth been so immediately coupled to vast engineering achievements. Because of the immediacy of these engineering demands and the unique requirements imposed, the role of the metallurgist has been a vital and fascinating one in the larger realm of nuclear science.

Picture, if you will, the plight of the nuclear engineer (if such an individual could be said to exist) in 1941 when the physicist presented to him the contemplated requirements for materials to build a "reactor". The fuel for this machine had to be uranium in amounts of many tons and of extremely high purity. Would the metallurgist please supply it in a few months? The average metallurgist knew that uranium was an element of high density, high atomic number and probably metallic properties, but little more. When he consulted the Metals Handbook, 1939 edition, he found under uranium only a few lines referring to the iron-uranium phase diagram. If he had an old Minerals Yearbook of the U.S. Bureau of Mines (1932-33 edition) he found only the following: "There are few if any practical uses for uranium as a metal. In the form of various salts it is used for coloring ceramic glazes."

Contrast our picture today – only 14 years after the need for uranium first became evident. Vast mining operations are carried out in many parts of the world to supply larger and larger amounts of ore for a chain of metallurgical operations, including large-scale metal production, fabrication, and incorporation into finished fuel units in reactors. More than 20 complete phase diagrams of uranium alloys have been worked out. The crystal structures of all three uranium phases, including the complex beta phase, have been established. The kinetics of transformation has been studied in detail and the effect of alloying elements on these transformations is becoming increasingly clear. The effect of fabrication operations and heat treatment on preferred orientation is now well understood, as is the relationship of these orientations to many properties. Casting, forging, rolling, swaging and other operations are carried out at any scale under controlled conditions, and some of these operations would seem difficult even to metallurgists used to much more tractable metals such as copper, aluminum, or steel. Finally – and most important (and difficult) – considerable progress has been made in understanding and to some extent controlling the damaging effects of radiation and fission fragments in this basic fuel.

Many details of this work on uranium still remain "classified" – that is, not in the open literature – but it has been, I believe, unquestionably the most important metallurgical aspect of nuclear energy. I say this in the face of many other outstanding achievements, some better known, some still unreported.

Zirconium (Hafnium-Free)

The most commonly cited of these other achievements is the rapid growth of zirconium from obscurity to a standard engineering material for nuclear use – all in the space of eight years. Three important events contributed most

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*Metallurgy and Ceramics Research Dept., General Electric Co., Schenectady, N. Y. (Formerly chief metallurgist for research division, U. S. Atomic Energy Commission).

to this startling development. First was the discovery that the published values for absorption of neutrons by zirconium were in error because the first samples tested contained a relatively large amount of hafnium (2 to 3%), which has a high absorption cross section. Retesting showed that zirconium would be high in the nuclear order of merit provided the hafnium could be removed. This separation had long intrigued the inorganic chemical fraternity; it was regarded as one of the most difficult of all, but as a result of concerted effort a satisfactory and inexpensive process was developed in the space of less than two years!

This is the second important highlight in metallurgical progress.

The third was the courageous decision of the designers of the first nuclear power plant for the submarine Nautilus to rely on zirconium as a basic structural material in the reactor. A simpler choice, metallurgically, would have been stainless steel, but the higher cross section of the 18-8 types would have required higher fuel inventories and lowered the performance.

The decision to go ahead with zirconium gave tremendous impetus to the work on this metal. When problems were encountered with the pure metal, alloys were developed. When metal production was not high enough, laboratories like the U.S. Bureau of Mines at Albany, Ore., became production centers almost overnight. Numerous commercial firms now have fabricating experience with zirconium and its alloys, and although it probably will not expand in tonnage production at a rate anything like titanium, it is a respected specialty metal made in quantities of 150 tons per year.

In passing it may be said that hafnium, the byproduct removed in the refining of zirconium, may also play a role in control systems for nuclear energy because of its high absorption cross section for neutrons and other characteristics.

Moderators – Beryllium and Graphite

In looking over the list of metals for possible nuclear use one is immediately impressed by certain outstanding advantages of beryllium. It has a relatively high melting point, is extremely light, has extraordinarily low neutron capture cross section and, being an element of low atomic number, it is the best of all metallic elements as a "moderator" for slowing down neutrons. In the early days of the wartime atomic energy project (the Manhattan District) an intensive study was begun on the problem of brittleness, which, together with high cost and questionable availability, prevented any engineering use of beryllium. In the past ten years a great deal has been learned about beryllium, as one can tell by reading "The Metal Beryllium", published last July by the American Society for Metals. Methods of fabrication by powder metallurgy, sheath rolling, hot and "warm" working have been developed and facilities now exist for producing the metal on a rather large scale. Nevertheless, it has not been possible by alloying, heat treatment, fabrication or other means to make beryllium or any beryllium-base alloy sufficiently ductile at room temperature to satisfy any but the simplest engineering requirements. Its cost is still high; its strategic availability is not entirely clear. In addition, the handling of beryllium in any operations which might possibly generate some dust must be done only with very rigid safety precautions.* The promise of beryllium has therefore never been realized. Although significant small-scale uses will continue (particularly where military value overshadows cost) it does not now seem likely that beryllium will be used on a large scale in the nuclear reactors of the future.

Graphite has also had a dramatic role in the history of nuclear materials. On the basis of cost and availability it was chosen for the moderators of the earliest reactors. It is still a favored material and is to be used as moderator in the large sodium-cooled reactor to be built by North American Aviation Co. for the A.E.C. as a prototype of a possible power-producing reactor. The first problem with graphite was to purify it in tonnage quantities – normal commercial graphites are too high in certain elements of high cross section (notably boron) to be satisfactory for use in reactors with natural uranium. Also, radiation damage – the harmful changes in properties that occur from bombardment by nuclear radiations or particles, particularly neutrons – is probably more spectacular in graphite than in any other nonfuel material. Electrical resistivity can be changed, for example, by large factors; the Hall coefficient can be reversed; lattice changes can be noted; thermal conductivity can decrease by as much as a factor of 50! These phenomena intrigued all those involved in nucleonics – the solid-state physicists in particular – and their studies have led to a more fundamental understanding of the mechanisms by which radiation damage occurs.

*The danger exists only in handling the metal beryllium, not its low alloys, such as the common and useful beryllium copper.

Thorium and Plutonium

I would also like to touch briefly on two more fuel materials – or perhaps I should say a potential and an actual fuel. The potential one is thorium. Although not fissionable in itself, it can absorb neutrons and pass through a series of radiative changes ending up as U^{233}, which is a relatively stable isotope and a fuel as well. Thorium has always been a source of amazement to nuclear metallurgists. It is a ductile, body-centered cubic metal, easily fabricated, metallurgically very well behaved and with only one phase change very near the melting point. Somehow it has no business among the orthorhombic, or the very brittle, or the very scarce, or the 5 or 6-phase metals of the nuclear world; but there it is, and for this small area of reason and sanity the nuclear metallurgist is duly thankful.

Plutonium, on the other hand, is as fantastic as thorium is normal. Six phases have been reported between room temperature and the melting point at 1185° F.! It varies in density in these phases from 15.92 to 19.74. It has a negative coefficient of expansion in the delta and the delta-prime phases! And it is highly alpha-radioactive and violently toxic because of its predilection for concentrating in bone marrow where its radiation can cause fatal anemia. Little more than the above facts have been released on this amazing metal, but these are enough to give some idea of the difficulty of the plutonium metallurgy going on behind the classification curtain. When secrecy is removed it will still be hard for the average metallurgist to comprehend the difficulties under which the work has had to be carried out. It has been a tremendous job well and painstakingly done and all those in the field, but particularly those at the Los Alamos Scientific Laboratory, deserve a great deal of credit.*

Radiation Damage

A final topic deserves some attention – namely, radiation damage. Nuclear reactors have added one more environment, the radiation field, for the metallurgist to cope with. In the early days of nuclear energy it was hard to tell how serious a problem this might be and a great deal of work had to be done in the past 12 or 13 years merely to understand the problem. It is now clear that the effects of nuclear radiation on organic materials can be far-reaching – usually detrimentally so – but some useful changes may also be possible. As to metals the problem looks less severe. Where a metastable system is concerned, its transformation to a stable phase may be caused or accelerated by radiation, but where a stable metallic system is involved the changes which occur are not normally of engineering significance to the properties at room temperature. (An exception to this may be the effect of radiation on ductile-to-brittle transition temperatures.) Another area still only poorly understood is the effect of radiation on corrosion rates. The most important problem, however, is in metallic systems containing fissionable fuels. Here the effects of the passage of highly energetic fission fragments – eventually perhaps akin to alloying effects – can sharply limit the operating life of the composite fuel elements.

As to Tomorrow?

This capsule report of past history and present status raises also the usually fatal possibility of trying to predict the future. It seems to me that in the nuclear field a number of facts or trends are evident. First, the achievements of the future are likely to be less dramatic than those of the past 15 years, unless discoveries in physics open up new and unexpected vistas. The first great search of the periodic table is over and it seems unlikely that any major program on a new element will rival those which have taken place on uranium, thorium, plutonium, zirconium, or beryllium. The job ahead is one of alloy development, of improvement, of fabrication, of cost cutting.

The future of industrial nuclear *power* depends on economics. It must be made competitive with conventionally fueled plants if it is to grow as an industry and this problem is largely in the hands of engineers and metallurgists.

In addition, valuable supporting uses may be found for rare-earth metals, for columbium, vanadium or for "new" materials. Radiation and corrosion damage studies in nuclear fuel and heat transfer systems will continue to be important and yield significant advances.

Even though nuclear metallurgy appears to have settled down now to a pace more nearly equivalent to that of other aspects of practical and fundamental metallurgy, yet in the background lurks always the possibility that new discoveries about the way energy is released from the nucleus will bring astounding new problems to challenge and delight the metallurgist.

*Some of the problems and accomplishments were described by Cyril Stanley Smith in "Metallurgy at Los Alamos, 1943-1945", *Metal Progress*, May 1954, p. 81.

Copper and Its Alloys

*By JOHN R. FREEMAN, JR.**

Copper has met the challenge of substitute materials by modernizing its equipment and introducing fundamental research into an old industry. (Cu)

COPPER, the oldest of metals, still stands among the most useful of metals. There is a saying that "nothing serves like copper", although in recent decades science and all of its research facilities have endeavored to find its equal. Copper water tube was found among the ruins of ancient Egypt and it is still a requisite of modern home and building construction. The pure metal copper is the same as the copper of prehistoric times, but in the last half-century production techniques and metallurgical knowledge have advanced to an astonishing degree. The natural properties of copper – corrosion resistance, workability, electrical conductivity, and ready alloying properties – have been its strength and yet, in a sense, its principal weakness. They have made it a target for substitution; many have tried to find another metal that would be suitable, or almost as good.

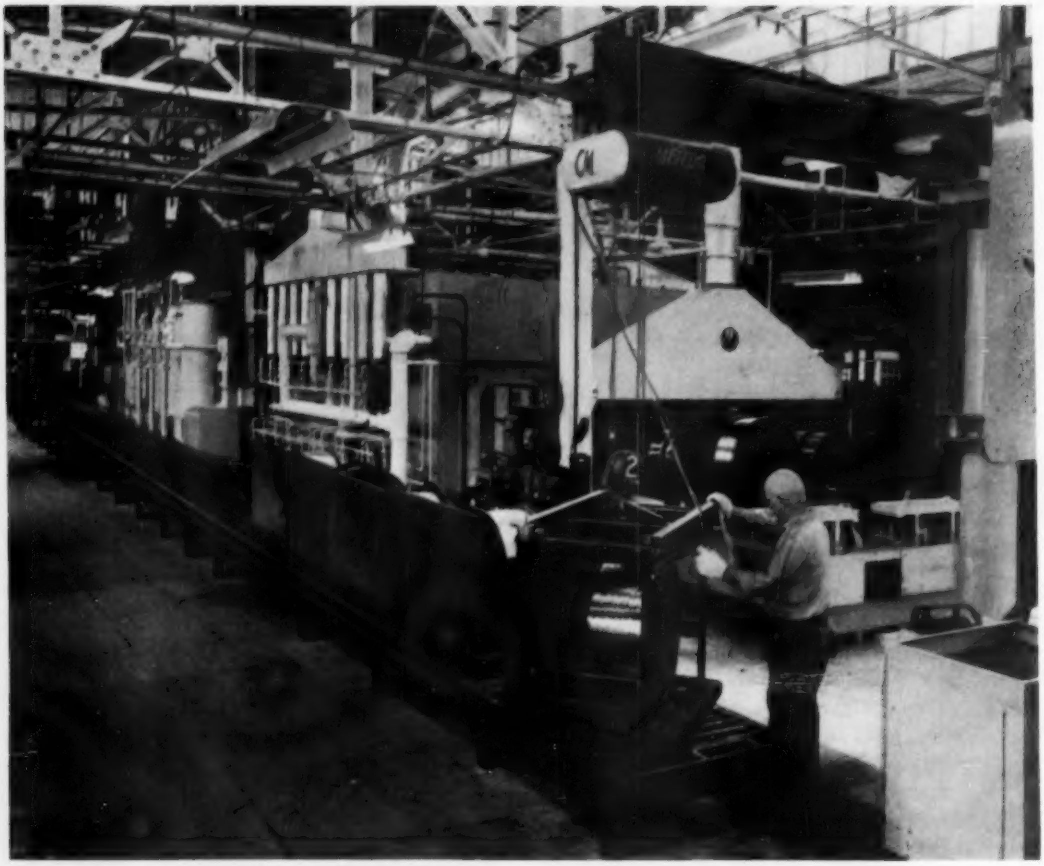
Another factor has operated in the same direction: Wartime and even peacetime demand has caused shortages which have encouraged industry, and particularly the American Government, to embark on extensive programs to find substitutes. The success of some of these endeavors eventually brought a realization that copper and its alloys are not entirely indispensable. Many reasonably satisfactory substitutes for certain specific uses have been found in places where aluminum alloys, stainless steels and plastics are adaptable. (Note that all these materials are phenomenal infants in comparison with copper, brass and bronze.)

For some time the copper industry was content, and to a degree is still content, to rest on the historic laurels of its indispensable and "everlasting" properties. However, the past two decades have seen a great awakening and realization that healthy competition existed not only within the industry but had penetrated from without. Copper had become simply one of the family of metals required to meet the growing demand of an ever-expanding economy. Competitive materials had suddenly come of age, aided of course by shortages in a metal whose ores are none too plentiful and usually low grade – even 1% copper or less. Industry found it could not be dependent on an unstable supply of copper and so turned to other materials, found they could be used and, once having changed over its manufacturing facilities, has not returned. This brought about the awakening. Recognizing the challenge, the copper industry tried to meet it – at first in a rather unbelieving manner.

Gradually the value of fundamental research – proven in the new competitive industries that have grown out of the laboratories – was recognized among those who held that tradition and practice are sacred. New concepts of the properties of copper and its alloys were engendered; new alloys were developed, and copper was recognized as an engineering material.

Copper, of course, had grown with, and still dominates, the electrical industry. The electrical

*Vice-President, Metallurgy and Research, American Brass Co., Waterbury, Conn.



An Example of Modern Equipment, Especially Engineered for the Copper Industry. An annealing furnace, attended by one man, heats 6250 lb. of copper wire per hr. to 900° F. at Anderson Mill of the Anaconda Wire & Cable Co.

conductivity of copper is unsurpassed by any commercial metal. This fundamental property of the metal is changeless with time. Neither the youthful and vigorous competitor, aluminum, nor any other known material, can ever match copper in this inherent property. Aluminum must always remain a substitute for electrical conductors, and in this field it finds use only when costs – economics – rule. More than 50% of all copper produced is consumed in the electrical industry in some form of electrical conductor. The remaining percentage, as pure metal or alloyed, emerges in a great range of diverse products. For example, in the relatively pure state it is used for such corrosion resistant products as roofing, gutters, flashing, and water tube in the building industry, or for the construction of a great array of chemical processing equipment. When alloyed, it is found in the innumerable and ubiquitous forms of the brasses, bronzes, and special alloys, ranging in size from zippers to monumental statuary and in utility from screws to plumbing fixtures.

The brasses and bronzes were known to the ancients, as was copper, and even today the mythical "secret" of hardened copper is often rediscovered. Old myths and traditions rarely die but do fade away. The number of copper alloys is legion. The fact that it can alloy readily with almost all metals (particularly the common ones like zinc, tin, silicon, aluminum, nickel, lead, and chromium) providing a variety of physical and chemical properties is, of course, one of the most important reasons for its widespread usefulness. Excellent formability and resistance to corrosion, combined with good mechanical properties, are the particular attributes of these multitudinous alloys. The discovery and develop-

ment of the silicon bronzes, such as the well-known Everdurs in the mid-1920's brought about the first real recognition of copper as the base of a whole series of engineering alloys. The silicon bronzes were the first to combine corrosion resistance with mechanical properties approaching those of the mild steels, with the added advantage of ready weldability. They are truly engineering materials. A new era in copper alloys was begun.

The growing insistence by the consuming industry for low cost, coupled with increasing scarcity, forced a detailed study and re-evaluation of the physical properties of copper alloys so that components and structures could be fabricated to smaller size and lower weight. This demand emphasized the need for adequate testing laboratories and initiated an era, over the past 25 years, of diligent study by important producing units in the American industry of the basic physical properties of copper alloys. With it came the obvious attempt to find the perfect alloy of high strength, ductility, electrical conductivity and corrosion resistance, coupled with good machinability and working properties – all to be easily manufactured at low cost. The millenium has not been reached but the effort has brought forth many new and useful alloys for specific purposes, and they have changed the whole pattern of the copper industry.

These same interests developed a need for a better understanding of the basic metallurgy of copper alloys. The production practices of the industry had developed by a "cut and try" technique, and much of it was (and often still is) steeped in tradition handed down from father to son. The old-time caster carried formulas under his hat; alloy compositions were secret and chemical analyses were infrequent. Composition was more often than not determined by the color and appearance of a fracture. Annealing temperatures were judged by the only optical pyrometer available – the eyes of an experienced man who kept his knowledge to himself.

Science was really first brought into the brass industry shortly after the turn of the century, and in this fundamental change the name of the late William H. Bassett of American Brass Co. shines prominently. Chemical laboratories were built for control. The development of pyrometers permitted the first relatively precise temperature measurements. Copper and brass were scrutinized under the microscope and the whole field of metallography and knowledge of grain structures was born. But it was only after World War II that the potential impact of science on the brass industry really began to be recognized by management.

The industry had prided itself on supplying tailor-made alloys in small, special lots to meet specific requirements. It was a "jewelry" business. The demands of World War II hastened the development of new, high-speed production equipment capable of handling much larger masses of metal. The development of the 4-high mill, permitting heavy reductions per pass and greater reduction between anneals, brought about a revolution in rolling practices similar to the revolution in casting technology at the time of World War I when the old pot-fired furnaces were replaced by electric melting furnaces. This introduction of heavy equipment in all phases of production, coupled with the demand for reduced costs, forced a detailed study of the fundamental metallurgy of all alloys – even the older and simpler brasses. The metal is no longer "babied" from casting shop to finished product. It is worked to its limit; so much so that the metallurgist has had to set up controls to prevent internal damage during processing! The old concept that copper was copper and brass was brass, and that all that was required was equipment heavy enough to "knock it down" to the size desired has, of necessity, been discarded.

The introduction of specifications in the procurement of materials, stimulated by government purchasing during the War, has forced the development of superior qualities and, in particular, a *uniformity* of quality undreamed by the early masters of the art.

The research metallurgist has met the challenge and introduced scientific control in brass mill operations. The mysteries associated with gases in metals, unsoundness in castings, inverse segregation, earing, coring, intergranular parting, and many others have succumbed to research. With a better understanding of the fundamental metallurgy involved, superior and more uniform products are manufactured. Of course, there are still many unknowns, but the quality of product today is meeting increasingly severe demands for performance, and is maintaining the proud leadership of copper and its alloys in the family of competitive metals.

The future for copper was certainly never brighter. There have been substitutions and there will be more in our intense, competitive, expanding economy; but new uses will be found for this ancient, yet ever-modern metal.

Metallurgy in Mass Production

*By L. A. DANSE**

Salty comments on the period from 1918 to now with one remark about what it means for tomorrow. (J general, G general)

RECENT popular clamor about "automation" reminds us that modern mass production has developed a great many interesting and highly effective labor-saving devices, not only mechanically, but metallurgically. As one who started out with Brown and Sharpe coke-fired furnaces for heat treating, dip magnets to check the human-eye pyrometer, hand tongs for conveyers, and home-made carburizing compound (even before we got the first platinum-rhodium thermocouples from Heraeus or Hanovia, with their porcelain "protecting" tubes, and D'Arsonval galvanometer indicators from Le Chatelier), this scribe can really appreciate all the Goldbergs that we now take advantage of.

For instance: When we started to build World War I Liberty aircraft engines, we had to speed up and do more work with less hands. We had preachers, streetcar conductors, barkeepers and schoolteachers in our heat treats, and only occasionally a farmer who knew how to work. And a lot of womenfolk, God bless 'em, who pitched in better than some of the men.

And the Liberty camshaft was a gismo, if ever there was one! It was long and limber and hard to handle or hold. Nonetheless, the machine shop expected the hardened shafts to come back to the grinders axially straight and with the cams in rotational register. Our furnaces were hardly what anyone would term highly mechanized, but the production schedule pressure was terrific, the accuracy demand insistent and, as usual, it was up to the metallurgists to deliver.

How?

By rigging up doors at both ends of a long, low furnace with slanting hearth, wide enough to take the length of the camshaft, then packing the shafts in carburizing compound in tubes and rolling them slowly down through the furnace. That got away with the carburizing heat, but left the hardening problem still up in the air.

Heating by rolling through a furnace having metal rails on the bottom was unsatisfactory, but a taller and narrower furnace that would take the cams through vertically would work, as was proven by hanging clusters of shafts on racks in deep tubular furnaces. So another makeshift furnace was set up – a tall, narrow, long, tunnel-conveyer job. The shafts were hung ver-

*Retired; Long chief metallurgist for Cadillac.

tically from double hooks, and carried through by a haywire conveyer, which, while it broke down every other day, still did a job of getting camshafts up to hardening heat, straight and true. Now we were up to heat. Fine! But quenching by hand, vertically, in an ordinary tank, did not get the hardness required, and did not keep the shafts straight.

First move was to try rolling the hot shafts down an incline, to get them spinning, into pairs of rolls which would let them continue to spin, then dunking them horizontally into brine. This gave the needed speed of quench and the hardness required, but not the straightness. (And how! Power spinners had not yet been developed!)

So another quick move was to rig a string of vertical quench tanks, each with a series of four vertical pipes with rows of holes set to force heavy tangential sprays of brine against the shafts at the cam locations. The brine, cascading to the bottom of the tanks, was drained away. This provided high-intensity spray quenching.

The next trouble was puzzling, but was ferreted out and licked. The spray pressures and volumes were not equal at all positions, due to improper piping connections. When this was uncovered it was easy to fix, but it was a tough one to find. Once disclosed, we were all set to produce; quenching was followed by a bank of deep, vertical tempering furnaces that handled the required volume of production.

So we got rolling and we fired cams back at the grinders so fast it made them dizzy. But their dizziness took us in – *they* speeded up and cut corners to where, in a short time, most of the cams checked in grinding. The shop screamed and the heat treat squirmed. We checked the carburized case for excessive carbides and cut down on the hypereutectoid, but then ran into spotty hardness. No sale!

Next we raised the tempering heat and again got into hardness trouble. While we got rid of the cracks, what good was a soft cam?

Our Chief was an old bronco twister who had seen a lot of critters – and folks – do a lot of tricks. So he put on his spurs and headed into the shop. Horse sense indicated that both feeds and speeds were pretty high on the cam grinders. So, first jump, the Chief set back rotational speeds of both wheel and cam, and cut the feed in half. Yow! Good cams! Then the howl went up from the Grinder Boss: "Ya can't do that to me." But the Chief told him off sharp, and went up to Management. When they saw the cams ground O.K. without excessive speeds and feeds, they promptly ordered third-shift operation of grinders. And that was that.

However, then (as now) metallurgists found that life is just one thing after another. In no time at all connecting rods became a bottleneck. They were of the forked and blade type; and the forked rods, in heat treating, were cracking in the forks. Several were sawed and macro-etched, which showed laps, folds and wrinkled flow lines. Showing this to the Works Manager, the Chief got his foot in his mouth. The Works Manager stared at the macro-etches and then dibbed at the Chief, "Get your roller skates on and beat it to the forge plant and help them work it out." Yessir – we're off!

The forge plant was in a neighboring state and the train ride was rough and unpleasant – three junction towns, where the sleeper was bunted around. (Trains are always rougher in wartime.) Worse than that, the train got to Whangville, where we had to get off, at 5:20 a.m.! So we toothbrushed the sleep out of our eyes, staggered onto the station platform and were informed that the bus for Wireburg, where the forge plant was, left at 7:45. How to kill two hours in a town still asleep? Mr. Station Master suggested that there was a good little hotel up town where the cafe opened at 6:30. Solved! So the Chief and one of the engineers who had accompanied him, ankled uptown to the hotel – just a nice mile stroll with the mercury at 10° F.

Knocking the icicles off their noses, Chief and Engineer bent their congealed joints into a couple of chairs and Engineer says, "What you goin' to have?" to which Chief rejoins "Coupla poached eggs, some sausage, whole wheat toast and coffee – yea, and some wilted lettuce salad." Engineer's eyes grew round with wonder, his jaw dropped, he gasped, and then exploded: "Wilted lettuce – hell! we throw it in the garbage when it wilts!" Chief grinned and rejoined, "O.K., wait till you see mine."

Came the waitress with the breakfast and first bite for Chief was a fork full of good old-fashioned German-style wilted lettuce, while Engineer stared unbelievingly. (The meal wound up with Engineer inhaling himself a dish of wilted lettuce.)

Then to the bus and on to Wireburg and the forge plant, where they were greeted with something less than enthusiasm.

Digging the macro-etched fork sections out of a sagging briefcase, Chief just laid them on the desk and suggested, "Let's go out in the

shop and fix it." There not being any appropriate rejoinder to that remark, out we went.

First operations on the forked rod were to swage, block, break down and forge the rod with the forked end solid. This needed only a glance. On to the next step – consisting of a hot saw to slit the fork, which also rated only a perfunctory look. Then to step No. 3, which was to drive a spreading blade into the slit. Here again, only a smell was needed: It stunk!

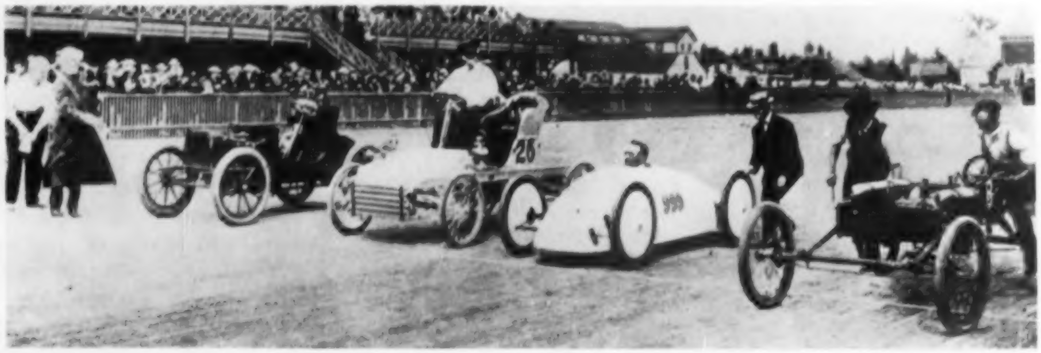
The saw kerf was sharp and jagged in the bottom; the spreading blade was rough and uneven at the end, just as jagged as the saw kerf. Jam the two together and you can't help but get wrinkles, laps and slivers. Grabbing half a dozen of the spread forgings and a couple which were sawed but not spread, the Chief asked to have them sectioned and etched. The forge-shop manager's jaw dropped and he was as wide-eyed as Mr. Engineer had been that morning over wilted lettuce. So the Chief took the forgings into the die room, commandeered a power saw, cut the sections, hunted up a disk grinder, ground them flat, rough polished them and hiked them into the pickling room, where he snatched an acid crock, made up a crude macro-etch solution and soaked the sections.

Within an hour, this display on the Manager's desk exposed the matter. The forge people were cautioned to control the heat on the hot sawing furnace, keep the hot saw clean and sharp, well rounded and sprayed with warm water. The spreading blade was to be better rounded on the nose, polished smooth, made from heat resisting steel and lubricated with high-flash tempering oil. The gibbs on forging machine slides were to be tightened to improve alignment and the gripping dies dressed and trued up to put the spreader blade exactly into the saw kerf.

All this involved a two day shut-down and the Forge Manager yelled to high heaven that the Chief's company's expediters were putting on pressure for immediate shipments. The Chief gave this argument the fishy stare and tersely remarked, "Fix it, first." The Forge Manager wouldn't listen and called the Chief's purchasing manager long distance, wailing about the hold-up. The P.M. evidently asked the Forgeman why the Chief was in his hair, because F.M. wilted perceptibly and "Oh welled" and "All righted" for a minute and hung up, then turned to the Chief, grinned, said, "You win, come on out to the country club and have a steak on me; we'll get going and work round the clock."

In a day and a half, forgings were coming off the spreaders with clean flowlines, no laps nor folds, and out the shipping room door faster than they ever had!

Speed Trials in 1902. Note No. 999 which made 104 mi. per hr.! (Courtesy Baker-Raulang Co.)



But did I say, life is just one . . . thing after another?

Back at the home plant, the Chief no sooner stuck his face in the door than three people yelled at him, "We're stopped on saucer gears!" Maybe you've forgotten what a saucer gear is, but the Liberty engine camshafts were driven by gear trains which included one piece about the size of a saucer, with splined holes in the hubs, half a dozen weight-reducing holes in the webs, and bevel gear teeth in the rims. They were of medium-carbon, medium-alloy steel, heat treated for toughness and good wear, heated in a push-through furnace and quenched in a fixture.

Gleason presses were not available. Neither were any others. The fixture was a long-handled waffle iron surrounding contoured die faces. The shapes of the die faces, the pressure exerted by

the waffle-iron and all the details had been carefully designed by trial and error, even including the size and location of the holes through which the quenching oil flowed.

Yelping, "Get Rudy" (the toolmaker who had made the waffle iron), the Chief bolted for the saucer gear furnace; maybe a burr had been raised on the die faces, or some unnoticed dirt had caused the trouble. A quick check showed that the temperature was O.K., the operator was going through the right motions, the oil flow was adequate – everything appeared all right, yet the gears were crooked. The floor inspector had checked the green gear and it had correct dimensions. By then, along came Rudy. The Chief told the operator to unload the furnace and Rudy picked up the waffle iron. In his careful, methodical way, he laid the fixture on the bench, looked it over and burst out, "Ach, some vun dhrop ihm on der floor," pointing to the bent hinge of the waffle iron. Top and bottom dies had shifted sideways and the rim of the saucer gear was part clamped, part loose. The Chief took a look, told the operator to shut off the furnace and said, "Rudy, how long will it take you to make a new hinge four times the size of that so it won't bend?" Rudy grinned and said, "You call my Boss and ihm the order give and I get it in eight hour." With a "Good boy, Rudy" and a slap on the back, the Chief beat it back to the phone and explained the emergency to the toolroom foreman, who promised a red-ball repair order, with extra help for Rudy if needed. Late that night, the furnace operator and the Chief were there when Rudy brought back the waffle iron. And saucer gears once more began to go to the grinders, ready to finish.

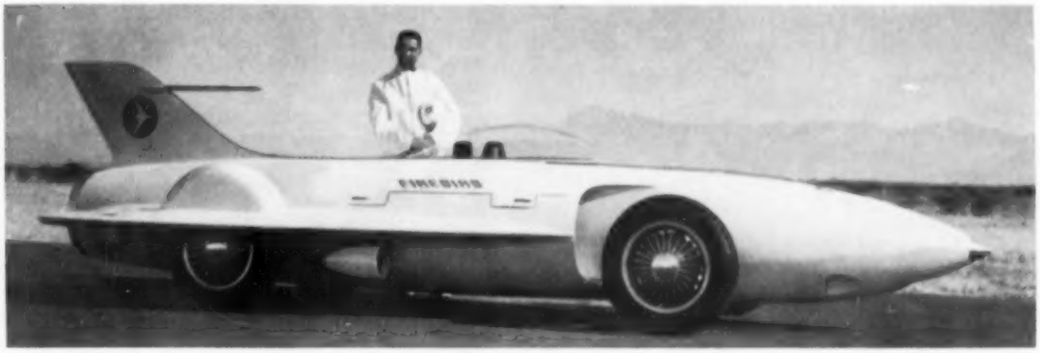
Practical metallurgy usually involves human or mechanical aberrations.

Coming in a few days later, with everything in the forging, heat treating and allied lines under control, the Chief met a phone message from the methods and time-study supervisor, asking him to come over and look at a press job that was causing too much scrap. The part was made from 1045 steel. It was roughed out on the automatics from cold drawn bar of correct hardness and strength. It was then press formed, cross-drilled and reamed, and finally finish ground on a centerless. Trouble was that the parts were splitting in press forming. Seamy stock – the standard culprit – was promptly ruled out; the lab boys had already checked that and the stock was clear and clean. Together, Methods and Metallurgy walked out to the press.

The press super had seen them coming. After watching about two dozen pieces come through, about a third of which split, the Chief opined, "That press is running too fast." The press superintendent stuck out his jaw. "What do you mean, too fast? I set that press speed myself." The Chief just grinned. "I wouldn't know, but it's still too fast." By then the press super was really on the prod. The Chief asked to shut off the drive motor. A blank was placed in the die, the Chief and the operator grabbed the flywheel, and together they pulled the press through its cycle, slowly, by hand. The piece formed perfectly. Then, with another blank in the die, the Chief kicked the press over at about half the set-up speed, by joggling the driving motor controls. A perfectly formed piece, repeated successfully eight or ten times. Then, a dozen pieces were formed at full set-up speed.

Three of them split.

Shutting off the press the Chief turned to the



The First Gas-Turbine Automobile Built and Tested in the United States. (Courtesy General Motors Corp.)

others and slowly said, "Look fellows, I've explained to you that metals take time to flow. Cut down the time and the mass can't flow, it shatters. Ed, when did you speed up this job?" The methods man grinned and said, "Last Tuesday. We thought we could get out production in eight hours instead of 12 or 13, but I guess it won't work." A red-faced press super swallowed hard and then came clean; "O.K., Chief, this one's on me."

Keep Things Moving!

So it went from January to November 1918, a war year. While the Chief cultivated his fields and mended his fences and fed his stock, he took time out to visit with the master mechanic and chin about tooling and machinery and equipment problems. He strolled over to the methods and time study on the way back from lunch and suggested that the standards people study welding and heat treating and forging problems as well as machine shop, press shop, and assembly jobs. The plant engineer was not overlooked. The Chief had worked in other plants as a construction and maintenance man, and he knew how important it was to be friends with those boys. Inspection almost had a desk and chair for the Chief; he was there so often he was hand-in-glove with the whole crew. Every once in a while he carried a cheerful grin into purchasing, until, when he'd stroll in, someone would holler, "Hey, Chief, I was going to call you—"! Regular, but not frequent, visitor to personnel (never know when, nor from where, you might need help). Not a day passed but some contact was made with one of the engineering staff and with one of the shop superintendents.

One place he studiously and assiduously avoided was the Boss's office. Quoth he, "The Boss knows where I am if he needs me. If he doesn't need me, my job is to keep things moving, not to bother him."

* * *

So what, you say. That's ancient history. That was 1918.

Yes, it was. But it happened again in World War II, almost cut to the same pattern.

And again during the "police action" in Korea. It happened in one plant, and another – in fact, all over the country.

The idea of a metallurgist as an inquisitive, persistent, always-ready-to-help trouble-shooter really took hold. The oldtimers knew it. They made good use of it. But that didn't keep things fixed. New problems were constantly turning up. New materials caused some of them. New supplying sources caused others. New methods, new machinery, new equipment, new processes caused many more.

Plus one factor, often overlooked, which causes more problems than frequently realized; this is the turnover of people, staff, workers – just folks. Every few years, industry has a new generation to train! The younger folks haven't met up with many old situations; they have to learn the same old lessons and a lot of new ones. Naturally production rates go up, mechanization is improved, automation is attempted, new controls are devised. But after all, *people* have to set these new devices up and keep them in motion and functioning properly.

If he is alert, the metallurgist can catalyze and synthesize these forces and keep them working smoothly. Not by himself, God knows; none of us is that good! Not only must he apply his own knowledge of materials and processes – he must have a lot of friends throughout his plant and among his profession. Let them in on any of his troubles! Who knows which one might come up with the right solution?

The bigger grow the production schedules, the greater the quantities of materials processed, the more intricate the operations, the more ponderous and complex the equipment, the more essential that people work together, and nobody should be better able to catalyze these human reactions than a sound-thinking engineer knowing a lot about metals and the other materials everyone must work with – *if* he himself is humble and gets those about him in on the act.

Remember always that the surest evidence of honesty of purpose is to speak in words so simple and clear that everyone understands you. Save the technical lingo for your scientific friends and for papers to learned societies or publications. Never forget that your very success may depend upon some unschooled operator carrying out your instructions. Never forget that your boss is too busy to have to stop and try to figure out what you're driving at when he reads your latest report or memo.

When you do this, you'll not only catalyze, you'll synthesize! You can't keep from growing when you quit trying to be profound. You'll be right on top of mass production.

* * *

Maybe that fills Ye Editor's request, which was that I tell something about the metallurgist's place in mass production, how he got that way, and where he will go from here (if he is wise).

Carbon and Alloy Steels

*By MAX W. LIGHTNER**

The quality of low-cost steel has increased steadily in the last 25 years because of better understanding of the fundamental factors that influence physical and mechanical properties. (ST)

THE ADVANCES experienced in carbon and alloy steel production in the past 25 years have been characterized by tailoring the steel shape, surface, analysis, and metallurgical characteristics to suit the intended fabrication and application. Today, prior to manufacture in large tonnage, the steel producer has nearly always investigated thoroughly the ultimate uses and has fashioned the quality of the steel to the required job. In addition, increased knowledge of the behavior of the wide variety of available steels has markedly increased the serviceability of manufactured goods.

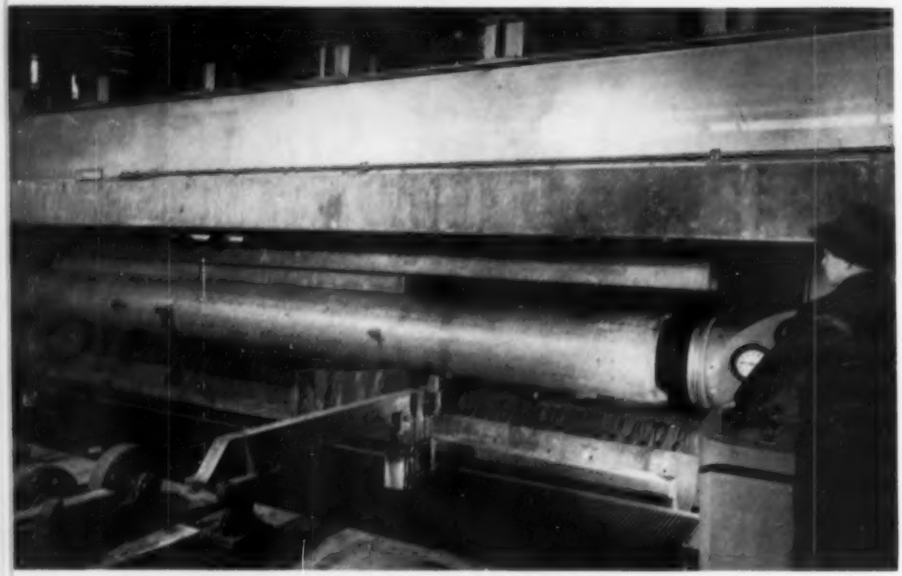
The change from ductile to brittle fracture in both carbon and alloy steels as test and service temperatures decrease has attracted the attention of consumer and producer alike. Many studies have been conducted on the effect of processing methods upon this change as well as the influence this change has on performance. As a result, steel consumers frequently specify minimum ductility requirements at subfreezing temperatures under certain service conditions.

The construction of all-welded ships, more than any other single circumstance, brought to light the importance of notch-free design, of proper fabrication procedures and freedom from defects, and the necessity for using steels of adequate notch toughness at operating temperatures in places where local stress concentrations may be high and cracks can progress across joints without interruption. Ship steels of improved notch toughness have been obtained by lowering the carbon and raising the manganese content, and, in the heavier gages, by fully deoxidizing with silicon and aluminum. It is recognized that improved toughness is also obtained by normalizing and by finer ferritic grain size. Ship casualties have been practically eliminated by using these measures in newly constructed hulls. In other applications where better toughness is required, the same steels and fabrication methods are also being employed successfully. To make heavy-gage plates more available under emergency conditions there are indications that satisfactory, or perchance even superior, plates may be obtained from semi-killed steels of higher manganese and lower carbon contents than are now common for intermediate-gage plates.

Sheet and Strip for Cold Forming

The modern demand for the automobile, the household refrigerator, stoves and other appliances, the tin can and galvanized roofing and siding, has been accompanied by the perfection of methods for sheet and strip production – the continuous hot strip mill and the tandem cold reduction mill. Most of the present-day sheets for deep drawing are produced from rimmed steels, which, by virture of composition and mode of solidification, have a very good surface. However, rimmed steel has some serious drawbacks; it is subject to aging during storage and to stretcher-strains in drawing. To avoid these disadvantages, special aluminum-killed steel was devised for use where cold forming is too severe for rimmed steel or where aging is a factor, by the addition of relatively large amounts of aluminum. However, its surface is generally inferior to rimmed steel. Better surface characteristics combined with the nonaging qualities of

*Assistant Vice-President, Research and Technology, United States Steel Corp., Pittsburgh.



A 40-ft. Length of 30-In. Welded Line Pipe Is Being Released From the Hydraulic Expander

aluminum-killed steel have been achieved with vanadium-treated steel. It appears to rim satisfactorily in the ingot mold and has less aging tendencies than rimmed steel, but has not yet been extensively used.

Until recently it has generally been believed that an isotropic material is more suitable for all types of forming operations than sheet with directional properties. It is now known that the plastic anisotropy characteristics of a material must be suited to the symmetry of the forming operation. For this and other reasons the problem of supplying sheets for the myriad of present-day applications has become one of producing suitable quality to meet specific drawing requirements.

That steel could be successfully drawn and formed to produce artillery cartridge cases was demonstrated after more than a decade of experimentation. The development of practical methods for cold extrusion of steel, resulting in a minimum of process scrap, improved surface finish, accurate size and in high tensile strength without heat treatment is considered to be one of the major technical developments in steel fabrication. The same principles are now being applied to cartridges for small arms.

In the past quarter-century the steel industry has seen continuous electrolytic tin plate replace hot dipped plate; continuous galvanized sheets supplant hand-dipped sheets; and the advent of aluminum-coated sheets and electrogalvanized sheets made in continuous equipment. Conceivably, the not-too-distant future will see the production of chemically treated black plate for many applications and a growing demand from the automotive and home appliance industries for organic-coated decorative sheets in many colors and designs. The invention of radiation gages together with electronic sensing devices for automatic gage control on both hot and cold strip mills is likely soon to result in strip more uniform in thickness.

Machinability and High Strength

The addition of lead to enhance the effect of sulphur on the machinability of steel is now a well-established practice. Recently, lead additions have been made to many of the plain carbon and low-alloy constructional grades. Another effective approach to improved machinability has been the control of the nature of the sulphide inclusions by controlling maximum silicon content and rolling conditions; the advantage of a globular sulphide inclusion over the elongated stringer has been amply demonstrated. Recent swings from the long-established bessemer free-machining grades to openhearth steels with and without added nitrogen and phosphorus have been successful. The future undoubtedly will see many consumers of free-machining steel install tools capable of operating at higher production speeds, thereby requiring further improvement in the raw material.

Cold expansion of welded line-pipe, either by hydraulic pressure or by mechanical methods,

is now being done on pipe up to 36 in. in diameter. By these methods the normal 45,000-psi. yield point of 0.25% carbon, 1.00% manganese steel is increased to a minimum of 52,000 psi. With such pipe oil and gas can be transmitted more cheaply at higher pressures for longer distances, thereby making these convenient fuels available in many parts of the country where they do not exist naturally.

In 1930, structural steels had a minimum yield strength of 33,000 psi. and tensile of 60,000 to 72,000 psi., with the possible exception of those grades used in a few large bridges. At that time, railway engineers expressed a desire to eliminate the excess dead weight in rolling stock and a wide variety of steels with 50,000 psi. minimum yield point and 70,000 psi. minimum tensile strength were soon marketed by the steel industry. To perform adequately it was imperative that these steels display good atmospheric corrosion resistance, satisfactory weldability and good formability. For obvious reasons, emphasis in design has changed within the last few years from light sections with weight savings to heavier sections with increased life and reduced maintenance costs.

Alloys in Steel

A notable advance made during World War II resulted from the recognition by both producer and consumer that the degree of hardening – or more specifically, the range of depth of hardening – was often of greater importance than chemical analysis. The propensity of a steel to harden depends upon its austenitic grain size at the time it is quenched, as well as upon its composition. Even the chemical analysis may not necessarily represent the true composition of the austenite since there may be undissolved carbides at the quenching temperature which will restrict the depth of hardening. As a result, so-called hardenability bands were established, mapping the upper and lower limits of depth to which various commercial grades could be hardened. It is of interest that the production of steels to H-band specifications, which represented 6% of the total production of alloy bars and semifinished billets and blooms in 1947, increased to 21% in 1954 – three and a half times.

A few years prior to World War II, fundamental studies of the effects of the alloying elements upon steel brought to light two significant facts: First, the properties of a steel part are largely a function of its microstructure rather than its composition; and second, a larger cross-sectional part may be hardened throughout if smaller quantities of several alloying elements are used rather than larger quantities of one or two elements. The latter fact was a corollary of the modern concept of hardenability and recognizes that the cumulative effects of the alloying elements on hardenability could be evaluated by multiplying the basic hardenability values (in terms of ideal diameter of a pure iron-carbon alloy) successfully by factors expressing the individual effects of the alloying elements. This knowledge led to the rapid formulation of a wide variety of steels known as the National Emergency (N.E.) steels, and conserved great amounts of scarce alloys and thereby met the wartime alloy steel demand. Although the older high-alloy engineering steels have since regained some of the ground surrendered to the N.E. steels, they are not likely to resume their former position of dominance.

The first record of the remarkable effects of extremely small quantities (0.0005 to 0.007%) of boron upon hardenability appeared in Germany about 1924. Much research was conducted during World War II, but it was not until the critical shortage of nickel and molybdenum required for jet-engine parts and other uses during the Korean episode that boron-containing steel was produced in notable tonnage. Strangely, even though as much as 10.5% of the alloy steel produced in 1952 contained boron, the quantity decreased to 7.2% of the alloy steel in 1954. Any extended restriction on the use of the common alloying elements will undoubtedly see an expanded use of boron. Manufacturing practices to produce boron steels are now well established and the hardenability effects are well known. Although it has been amply demonstrated that boron suppresses the formation of pro-eutectoid ferrite during continuous cooling of austenite, the exact mechanism whereby it imparts *depth* of hardening is still not fully understood. In this country, boron steels are largely used in the quenched and tempered state, but in England a molybdenum-boron steel is produced with less than 0.16% carbon, reportedly with a yield point exceeding 65,000 psi. in the normalized state.

Toughness at High Strength

Generally, the best microstructure for toughness at subzero temperatures in ferritic steels is a tempered martensite containing less than 0.20% carbon. By the judicious use of small quantities of several alloying elements, quenched and tempered constructional steels with yield strengths

Huge Loads Shock the Landing Gear of Large Aircraft. Ultra - high - strength quenched and tempered martensitic steels are useful here

exceeding 90,000 psi. and high toughness at subfreezing temperatures are being produced. Such steels, which are readily weldable without preheat or postheat, should find extensive use where superior toughness is needed at low temperatures and where weight can be reduced.

Much research is also being conducted on the effects of microstructure of quenched and tempered steels on the transition temperature, or the change from ductile to brittle fracture. Even though it is generally recognized that low-carbon tempered martensite is superior, there is some experimental evidence to indicate that low-carbon steels containing boron, treated to contain as much as 50% of the microconstituent known as lower bainite, may have even lower transition temperatures than those consisting entirely of tempered martensite.

Use of ferritic alloy steels at increasingly higher operating temperatures has stimulated studies on the effect of composition, microstructure, and processing variables on creep, stress-rupture and hot tensile strength. The metallurgical approach to obtaining desired properties depends to a large extent upon the ultimate use. Strength is generally increased by alloying, and, as expected, certain elements are more effective than others. Small amounts of nickel and cobalt are relatively ineffective; molybdenum is a very potent strengthener at high temperatures; chromium, manganese and silicon have intermediate effectiveness. Certain combinations of elements may be more potent than would be expected on the basis of their individual effects. An example is the remarkable, unexpected properties possessed by ferritic steels containing small amounts of titanium and boron, an analysis which, at the present stage of development, has the drawback that it must be hot worked within a narrow temperature range to avoid excessive cracking and its notch toughness leaves something to be desired for certain applications.

Creep properties of steels are greatly influenced by manufacturing variables such as melting practice (including deoxidation) and method of forging and rolling. The variety of microstructures assumed by ferrous alloys heat treated in various ways affect the creep-rupture properties depending upon time and temperature of testing. At shorter times and at lower temperatures of testing, the low-temperature transformation products — upper bainite, lower bainite and martensite — display higher creep-rupture properties than the transformation products formed at high temperature — fine pearlite and coarse pearlite. This distinction disappears, however, at longer times and higher temperatures of testing. Thus, where total exposure time is short, such as in rockets and certain jet-engine parts, the initial microstructure is important. On the other hand, for long-time elevated-temperature service, such as in steam turbines, little advantage can be gained by treating to a selected microstructure, and only the proper alloying combinations are effective.

Ultra-high-strength steels in the range of 200,000 to 300,000 psi. and above, designed primarily for aircraft landing gears, have appeared within the past few years. Generally speaking, they are formulated on the premise that the factors governing toughness at high hardness are (*a*) sufficient hardenability to obtain full-tempered martensitic microstructures, (*b*) the lowest possible carbon content consistent with the required strength level, and (*c*) a tempering temperature outside the embrittling temperature range. Several of these steels contain silicon in the range of 0.50 to 2.00%; this silicon raises the tempering temperature range at which embrittlement occurs, and, consequently, permits a wider range of tempering temperatures. Although originally intended for aircraft landing gears, there is an increasing trend toward putting these steels into other airplane parts where severe corrosion is not a problem. They have the advantage of strength-to-weight ratios similar to aluminum with much

less bulk, and often save weight significantly in interior structures. Since they have adequate notch toughness for critical aircraft applications and their fatigue strength is high, they should find future applications in machinery and equipment operating at higher stress levels than present designs.

Recent trials of the Ugine-Séjournet process (a glass lubricant to improve metal flow and die life in the hot extrusion of steel) will be followed with interest. Extrusion is an excellent method for small-order production, for special thin-walled tubing and difficult-to-roll sections, and increases the availability of valve steels and other grades of higher-than-normal production yields.

Within the last few years, interest in the effects of exceedingly low quantities of nitrogen, oxygen and hydrogen upon various mechanical properties has turned attention to the vacuum melting and casting of steel. Results of fatigue tests show that the endurance limit of S.A.E. 52100 and S.A.E. 4340 bearing-quality grades can be significantly increased by vacuum melting, which supposedly produces steel freer from nonmetallic inclusions. It has been predicted that the next decade will see many special alloy and forging steels produced in which the so-called "gas content" is held to a minimum.

Much has been said and written about the effects of the rare earths, cerium and lanthanum, upon many characteristics and properties such as rollability, formability, ductility and the ratio of transverse to longitudinal impact properties of carbon and alloy steel, and much more is yet to be learned, and said, and written.

The recent government decision to encourage utilization of nuclear energy for industrial power generation will require much new knowledge on materials of construction. Design engineers will demand reactor materials to operate at high temperatures and pressures, as well as to resist the corrosive action of unusual and very hot fluids used to transfer the heat energy. Furthermore, at least two types of radiation damage may occur to materials upon exposure; one results in a general hardening and embrittlement and the other effect involves the actual transmutation of elements. Metallurgical characteristics and the design of materials for reactors form an area of research which will receive increasing attention in the future, and is a matter of sufficient importance to receive a special article in this anniversary issue of *Metal Progress* (see p. 82).

In summary, it should be apparent from the record – so briefly stated in the above – that the tonnage steel producer has devised a great number of special products to meet the special needs of large consumers. Nor has there been any lack of attention to the old staples like sheet, wire, structural shapes. The record shows that new problems continually arise for solution, and that they are almost without exception being solved in an expeditious and economical way.

There is no reason to believe that the near future will be any different from the recent past. New problems will be presented in great variety. They will be tackled with vigor and intelligence and – we make bold to say – with great expectancy of success.

A Finished Steel Shape Emerges From the End of This Extrusion Press

Ernest Edgar Thum
Editor Metal Progress, 1930—

A Biographical Appreciation . . .

by William H. Eisenman

THE SHADOWY outlines of *Metal Progress* first emerged from the dancing flames of an open fireplace during a conversation I had with my neighbor, Marsh Powers, then head of a prominent Cleveland advertising house, in 1930. The Board of Trustees of the American Society for Steel Treating (which was A.S.M.'s name until 1934) had realized for some time that the rapidly broadening activities of the Society required a new and expanded editorial policy. Publication of convention papers in the *Transactions*, as in the past, was not enough. There was a wide open field for "practical" papers on the production, inspection, fabrication, treatment and use of metals. There was also a wide open field for introducing a format and style that would be more attractive to advertisers than the staid and academic *Transactions*. And so the idea of a "*Fortune* magazine of the metal industry" was born.

But no good idea is better than the man who gets behind it. Fortunate indeed were we to find the right person on an editorial desk at *Iron Age*. There was little difficulty in persuading Ernest Thum that here was the opportunity he had been looking for. He himself had once prepared extensive studies of a magazine of the very same type but the plans had fallen through. He seemed to have the vision and enthusiasm; moreover, his background provided the ideal combination of editorial experience, a knowledge of printing, and the broadest kind of metallurgical background including engineering, industrial public relations work, and academic experience as a professor of metallurgy. What we didn't fully realize was his enormous capacity for hard, concentrated work, his swift, sure judgment, his flare for artistic values, and an innate capacity for leadership.

Ernest does not look like the cowboy type; he would pass easier for an urbane New York businessman, or a polished connoisseur of the arts. Nevertheless, he was raised in Pueblo, Colo., graduating as a Mining Engineer from Colorado School of Mines (1906), and worked in western copper smelters for seven years before gravitating eastward. He still likes nothing better than to spend a few weeks at a Wyoming ranch exploring the Big Horn mountains from a saddle.

Ernest takes pride in his youthful accomplishments, when he lived the rugged life of a civil and construction engineer for the Anaconda Copper Mining Co. and its subsidiaries. For a youngster his responsibilities were large; he had charge of all field engineering on a seven-mile railroad and the construction of a four million dollar smelter. Then war broke out in Europe and all operations at Great Falls were suspended.

Some quirk of fate took him to the post of professor of metallurgy at University of Cincinnati in 1915, when physical metallurgy, metallography and heat treatment were entering their heyday. In his words, he "studied like hell to keep one jump ahead of his classes, and found that it didn't hurt a bit to say 'I don't know' to a student's question."

By then he had married his high school sweetheart, Clara Orr, and the pay of a professor made hard going of bringing up four children. Fate again took a hand and led to an offer from the McGraw-Hill organization to become associate editor for *Metallurgical and Chemical Engineering* in 1917. Five years later, it was transformed to *Chemical Engineering* and dropped metallurgy from its title and its interests.

So Ernest Thum hopped to the other side of the fence and became head of an embryonic technical publicity department of Union Carbide & Carbon Corp., where his mission was to acquaint trade paper editors and engineering professors with the advantages of oxy-acetylene welding as a production technique. In 1927 *Iron Age* offered him the post of principal associate editor, and that's where we found him in 1930.

Under Thum's guidance *Metal Progress* did indeed become "the *Fortune* of the metal industry". The editor insisted from the beginning on the very highest standards of printing, layout and typography. (The stature of the magazine today speaks for the technical excellence of the articles he solicited, suggested, wrote and rewrote.) But it wasn't easy and it wasn't all glory – the magazine was not yet on its feet when the great depression hit. For five years it was barely out of the red, but he and the directors of A.S.M. kept faith and the magazine has since repaid that faith hundreds of times over.

Ernest is an independent sort of person and the A.S.M. management and board gave him a free rein to achieve the prime objective as best he could. This confidence was not misplaced. He has been solely responsible for the important and distinguishing features of the magazine. The artistic and eye-catching front covers have been maintained since the beginning, principally because *Metal Progress* goes to its readers' homes, and Ernest likes attractive things in his home. The "Critical Points" are his own – a cross between an editorial column and a sort of diary of technical travels – concisely written and

widely acclaimed. The monthly data sheets have been republished in popular looseleaf collections. Ernest was one of the first to realize the significance of Hiroshima to the metallurgical engineer as well as to humanity, and since 1945 an "Atomic Age" page has appeared in nearly every issue.

For 18 years Ernest was a one-man editorial staff – editor-in-chief, managing editor, layout artist and reporter; yet somehow he found time to sandwich in a number of other important activities – and still does. He organized and edited the authoritative "Book of Stainless Steels", "Modern Steels", and a number of others; he helped plan and conduct discussion meetings at A.S.M. conventions; he addressed innumerable A.S.M. chapters on subjects ranging all over the metallurgical map; he took part in committee work for various other technical societies and professional groups.

He has also done a number of notable jobs for the United States Government. For example, during World War II he was a member of the original War Metallurgy Committee of the National Research Council and prepared extensive studies of secondary copper supplies. Since 1948 he has been a member of the U. S. Atomic Energy Commission's "Advisory Committee on Industrial Information", and headed numerous of its task groups. More recently he was a member of the Advisory Committee to the National Bureau of Standards and U. S. Air Force on "Potentials and Utility of Castings for Aircraft".

Perhaps his most notable committee work (at least for length of service) was for the American Society for Testing Materials. For 20 years he directed the activities of Committee B-2 on Nonferrous Metals, first as secretary and then as chairman, and for 10 years he was a member (and the first chairman) of Committee B-6 on Die Castings. In recognition of these services the A.S.T.M. last year presented him with its Award of Merit.

His only club is the Rowfant Club, a group of Cleveland men interested in fine books – a club similar to the Grolier Society in New York and the Sette of Odd Volumes of Great Britain.

But over the years *Metal Progress* grew and grew and A.S.M. grew and grew, and in 1948 an augmented staff became mandatory. At the same time Ernest's advice and guidance have proven so valuable in a number of extraneous A.S.M. activities that he has had no chance to slow down. Despite added help, the stacks of undone work on top his desk remain; he has come to regard them with philosophic aplomb rather than despair and somehow manages to clear his desk of the really important items.

Ernest sometimes uses the expression, "Let's get to the nub of the matter." Just as he shucks off excess verbiage in a manuscript, leaving only the essentials, clearly expressed, he is able to dig through the outer husks of detail on any problem and reduce it to fundamentals. So his advice is sought, not only in matters of A.S.M. management, but by his subordinates as well. Never too busy to help and suggest, nevertheless he lets them do their jobs in their own way. He expects the best and gets it; as one associate says, "When you do a job for him you feel as though you have accomplished something worth while."

The Thum family life suffered two tragic blows during the years; polio struck two of his children and left the youngest daughter, Dorothy, sadly crippled; then in 1944 his wife died of cancer. Dorothy, who inherited her father's fortitude and energy, now lives a happy life in France, writing occasionally and keeping house for her brother Charles, who is supervising architect for N.A.T.O.'s monumental new office building. The oldest daughter, Margaret, is married and lives in New Jersey. The youngest son, Bob, heads a construction firm in Cleveland. In 1948 Ernest married Margaret Sandt, and now has a charming and vivacious companion to share his travels and his interests in literature, music and double-crostics.

Honors have accrued to *Metal Progress* as well as to its editor. The magazine was an early winner in contests for editorial excellence sponsored by the National Industrial Advertising Association; its most recent award was the Certificate of Excellence of the American Institute of Graphic Arts for the outstanding entry in the Magazine Show of 1950.

In his estimation, his most prized award is the 1951 Silver Medal of his Alma Mater, the Colorado School of Mines, "for his personal excellence and distinguished achievements in the field of metallurgy".

Ernest believes in giving his readers what they want; but more than that he believes that an editor should lead. He maintains it is the editor's job to foresee important developments before his readers realize them – to point the way rather than wait for a clamor of requests. Thus he has kept *Metal Progress* ever in the vanguard of scientific and technological development – each issue a proud example of what its name implies.

Powder Metallurgy–Its Rapid Development

*By HENRY H. HAUSNER**

The unique advantages of powder metallurgy, formerly considered only for mass production of small parts, have opened a diverse and growing number of applications for the process. (H general)

THE RAPID development of powder metallurgy during the last few years came as a surprise to many engineers and even to many metallurgists who did not see in this process anything other than a method for inexpensive mass production of small machine parts. Originally an art, powder metallurgy processes have developed into a well-established metallurgical technique, and today the entire area has become an important part of the science labeled as "solid-state physics". Commercially, it has grown in the direction of new products and of new production methods and has created a new industry, which includes metal powder producers, parts manufacturers, and manufacturers of equipment such as presses, furnaces and vacuum equipment.

I have often been asked "How old is powder metallurgy?" According to several authors, the roots of powder metallurgy can be traced back several thousand years; other writers believe that the cornerstone of powder metallurgy was set in 1829, when Wollaston developed the process of making malleable platinum from platinum powder. The Russians claim the development of powder metallurgy in 1827. I personally feel that the starting point for modern powder metallurgy was closely connected with the development of the incandescent lamp. In this field Auer von Welsbach produced osmium wire by the extrusion of osmium metal powder. When Coolidge improved Edison's incandescent lamp, he had no other method than powder metallurgy for making the tungsten filament.

The advantages of powder metallurgy for this purpose were soon recognized and applied to other metals and combinations of metals. In 1908 Emery Gilson in Schenectady made metal-graphite combinations for motor brushes and bearings and in 1916 patented the essentials for oil-less bearings. A few years later Paul Schwarzkopf made "compound metals", such as tungsten-copper or molybdenum-silver, out of metals that do not form alloys by solid solution or intermetallic compounds. He mixed two or more metals in powder form, compacted and sintered them below their melting points. In this way the wear resistance of a high-melting component and the good electrical conductivity of a low-melting component, for example, can be combined to make high-quality electrical contact materials.

The writer, an electrical engineer by education, first became interested in powder metallurgy some 20 years ago, early in the lifetime of *Metal Progress*. Powder metallurgy and electrical engineering apparently helped each other develop; I refer especially to the powder-metallurgy production of cores for induction coils, magnets for electrical instruments, pole pieces for motors, and various other parts without which our electronic industry would not stand where it does today.

It was not always easy to obtain completely dense products by powder metallurgy. For a while, it was thought that the porosity of products then made from powdered iron, copper and other metals was a severe handicap to the new technique. Ingenious metallurgists, however, had already turned this disadvantage to one of the greatest advantages powder metallurgy can offer – the production of porous bearings (so-called

*Manager of Engineering, Atomic Energy Div., Sylvania Electric Products Inc., Bayside, N. Y.

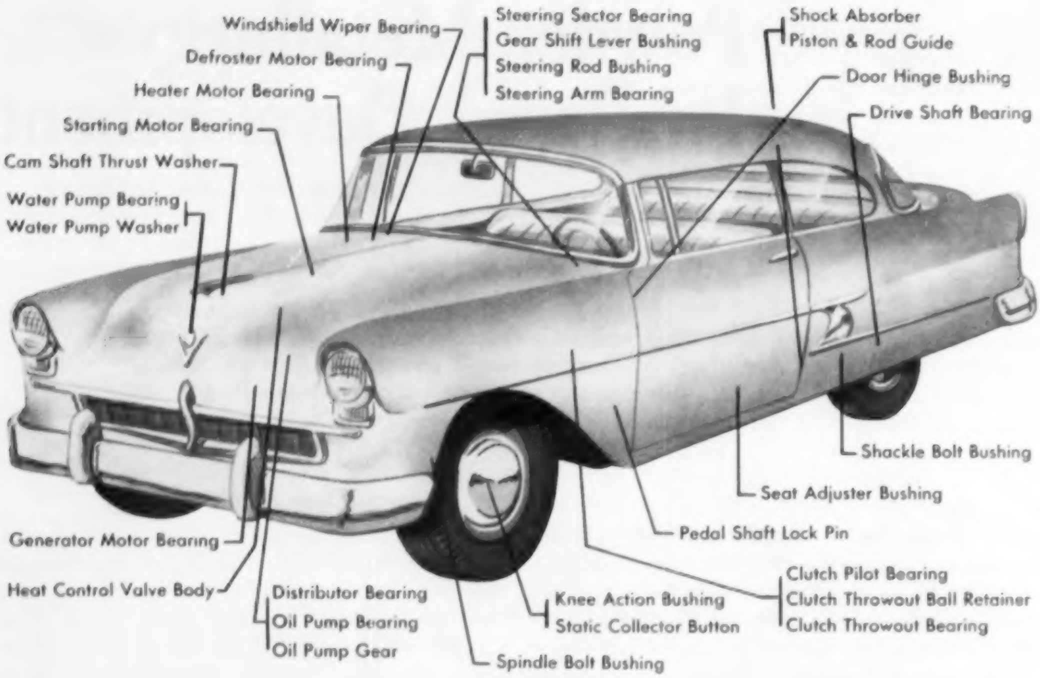


Fig. 1 – Most Automobiles Contain Between 60 and 70 Parts Made by Powder Metallurgy

oil-less bearings). Without these the small motor industry, the fan, refrigerator and air-conditioning industries could not have grown to their present importance. In the meantime, powder metallurgy products have also been developed without any porosity (100% density).

Practically every automobile produced in the United States contains 60 to 70 parts made by powder metallurgy; the most important ones are shown in Fig. 1. Four to five hundred million powder-metallurgical parts are used annually by the American automobile industry, consuming 10 to 12 million pounds of metal powders.

Growth of the Industry

The rapid growth of the industry during the past 15 years is indicated in Fig. 2. The curves in this figure show that more iron and copper powder is being used in the United States than in any other part of the western world. This is because parts made therefrom are used mainly in countries where mass production is important. The high peak in other countries occurred during World War II because the German war industry produced iron shell bands, fabricated by powder metallurgy, to replace the conventional bands of copper – then a very scarce metal. In passing it may be remarked that the powder-metal shell bands proved to be far superior.

Of the steadily increasing iron powder consumption in the United States, approximately 55% is used for bearings and machine parts, 27% for magnetic cores, 3% for friction parts, and the remainder for various other applications. More than 55% of this iron powder is imported, primarily from Sweden. The increase in iron powder consumption in the United States during the past 12 years is shown in Fig. 3. All these figures indicate the continued and healthy growth of the metal powder industry.

Franz Skaupy, one of the German pioneers, strenuously objected to the term "powder metallurgy" and fought for years for the term "metal-ceramics," reasoning that the technique is actually identical with the processing of ceramics – an established art for thousands of years. For a long time, there were many linguistic discussions between the "powder metallurgists" and the "metal-ceramists" until a compromise was reached when combined metallic and ceramic powder materials were produced commercially – true "cermets" which contain uniformly dispersed ceramic and metallic components. These combinations were first used as sintered mixtures of powdered carbides with a metallic binder for cutting or drilling tools. The more recent use of

cermets for high-temperature applications will be noted later.

There are more than 45 manufacturers in the United States and more than 60 in western Europe fabricating high-density iron parts. Most of them make copper-base parts as well. However, during the last few years, powder metallurgy has grown in various other directions as demanded for the many special applications and has been guided by a truly scientific approach.

Until a few years ago, hot compacting, which combines pressing and sintering in one processing step, was merely an interesting laboratory method. Today, hot compacting in air, vacuum, or protective atmosphere is a valuable production method for specialties which cannot be economically made in any other way.

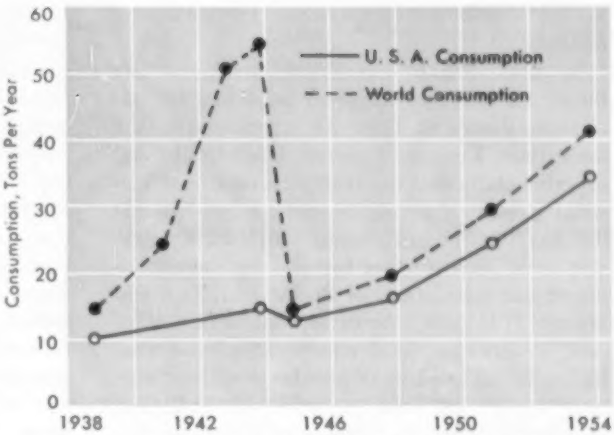


Fig. 2 – Consumption of Iron and Copper Powders in the United States and in the Free World

New Techniques Broaden Applications

Formerly powder-metal products were limited in dimensions by die size and press capacity. A few years ago, a process for compacting by powder rolling was developed, as shown schematically in Fig. 4. This method is already producing long metallic bands or sheets, either of high density or of controlled porosity, characterized by a randomly oriented fine grain structure. Copper, brass, iron or stainless steel sheets of any desired length can be produced at low cost.

The powder metallurgist has also learned to mold metal powders into complicated shapes by a slip-casting process, very similar to slip casting in ceramics. This process is still under development. Powder metallurgy is thus not limited to the conventional operations of pressing and sintering. Another excellent example is the addition of up to 50% iron powder to the coating of arc-welding electrodes, which has increased welding speeds up to 50%. The coating is extruded around the wire core as it passes through an extrusion press.

Combinations of two or more metals which do not form alloys or have but limited solubility can be produced either by mixing the component metal powders, compacting and sintering the compact, or merely by compacting and sintering the components of high melting temperature to a predetermined low density and adding the other component by infiltration. The simplicity of the latter technique is striking; the mechanical properties of the parts made in this manner are equally satisfactory.

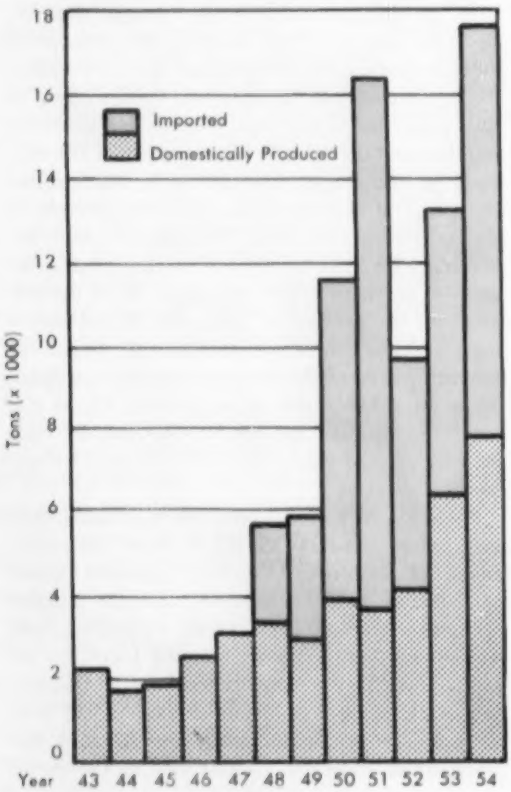
Powder metallurgy is also suitable for forming alloys by solid-state reaction. Ordinary melting of alloying components of different density frequently results in segregation of one of the components, and one or more remelting steps may be necessary to obtain a homogeneous structure. Remelting involves the danger that the material may pick up undesirable gaseous or solid impurities. Uniform mixing of the two alloying components in the form of powder offers no difficulties and subsequent compacting or sintering does not disturb the homogeneity of the mixture. An example is given in Fig. 5, which shows the effect of sintering time and temperature on the microstructure of a 4% uranium, 96% zirconium alloy. The large total surface area of the powder particles might pick up a lot of oxygen, nitrogen or "protective" gas, except that sintering usually occurs at temperatures far below the melting points of the components where solubility is on a low order of magnitude. Grain size can be controlled, and the product usually ends up with smaller grains than are obtained by any melting process.

High-quality sintered products were fabricated long before scientists started to study the mechanism of sintering. Bonding between metal particles as well as between ceramic powder particles was recognized, and the rate of bonding was known, but the theory was not. Jones, Sauerwald, and Skaupy contributed earlier theories and ideas, but it was not until after World War II that Frenkel scientifically investigated the process and proposed viscous flow of the metal

as the mechanism responsible for solid-state bonding.

In 1947, Shaler and Wulff developed this theory further, and Kingston published his nucleation theory in 1948. At approximately the same time, Kuczynski proved theoretically and experimentally that the bodily movement of material during sintering is caused by "volume diffusion" or "body diffusion". In 1954, Kuczynski's ideas were further fortified by the experiments and calculations of Bockstiegel, Zapf and Masing. It is known, however, that surface diffusion, evaporation, and condensation also contribute to the bonding of powder particles. From many discussions I have had with Richard Kieffer, one of the European pioneers of powder metallurgy, I came to the conclusion that probably all the above-mentioned sintering mechanisms can take place individually, successively, or simultaneously during the sintering process. I believe that the exact mechanism depends on the type of metal, method of fabricating the powder, and sintering temperature, time and atmosphere.

Fig. 3 – Total United States Shipments of Iron Powder (Data From Metal Powder Association)



The powder metallurgist recently learned that both the sintering process and the rate of sintering can be strongly influenced ("activated") by the addition of solids that evaporate during sintering, or by surrounding gases that increase the reactivity of the metal powders. Along this same line is the compacting of metal compounds such as hydrides instead of pure metallic powders. The compound decomposes during sintering, and powder particles are sintered in their *status nascendi* – that is, at the moment of greatest activity. This gives materials of practically theoretical densities at fairly low sintering temperatures. All these ideas on activated sintering and increasing the reactivity of powders are based on Hedvall's original research on solid-state reactions.

Cermets for High Temperatures

During the last few years, much effort has been expended in the development of composite metal-ceramic mixtures. The basic idea was conceived as early as 1886, when concrete was strengthened by a network of iron rods. We have already noted that cermets started with cemented carbides for tooling purposes; an enormous amount of work is concentrated on such materials for high temperatures in gas turbines and jet engines. As shown in some detail by Roger Long in his contribution to this anniversary issue, fine particles of oxides, carbides, borides, and silicides can be bonded by a metal. Some titanium cermets based on carbide are useful up to approximately 1800° F. and boride-base cermets, with a super-alloy type of binder, can withstand temperatures up to 2400° F.

Cermets should be mechanically strong at elevated temperature, must show a certain degree of ductility and must be resistant to corrosion and thermal shock. Many of the recently developed combinations, with only some of these desired properties, contain considerably more of the ceramic component than of the metallic binder. It is my opinion that this trend should be reversed, and that the next advance will be in the direction of the sintered (oxidized) aluminum product, nicknamed "SAP", of Zeerleder and his co-workers. These investigators fabricated a sintered aluminum, containing about 15% aluminum oxide, into parts which show excellent strength up to 840° F. Efforts are being made to combine a heat resisting metal powder with a smaller amount of ceramic powder in order to improve ductility and thermal shock resistance.

Our growing understanding of the fundamentals of powder metallurgy has enabled us to coordinate this technique with the requirements for materials exposed to neutron or gamma irradiation in nuclear power reactors. As noted by D. W. Lillie in this issue (p. 82), the powder metallurgy of uranium, thorium, zirconium and beryllium has been developed to a high degree.

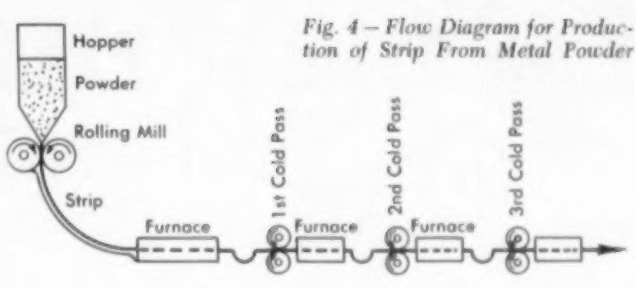


Fig. 4 – Flow Diagram for Production of Strip From Metal Powder

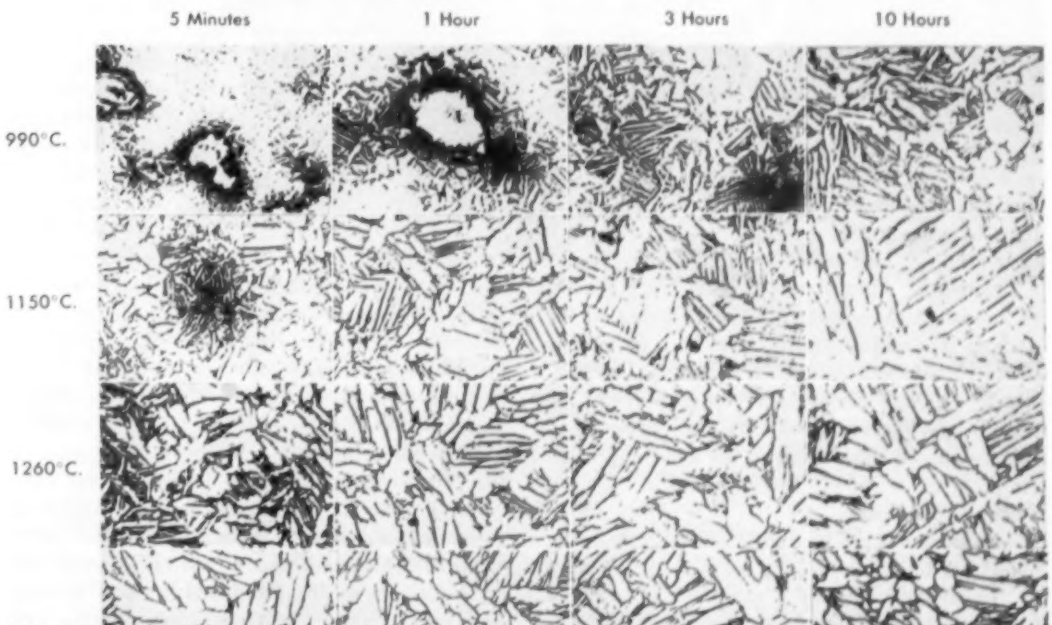
All these advances in various fields of engineering have encouraged scientists and engineers to work on new methods for producing metal powders and new compacting, sintering, and related techniques.

Before World War II, only two or three of our educational institutions offered courses in powder metallurgy. Interest in powder metallurgy grew during the war and increased enormously after its end. Of 37 institutions in the United States offering degrees in metallurgy, 31 (or 84%) now offer courses in powder metallurgy. These are not only of interest to students in metallurgy but also to those in mechanical, electrical, and chemical engineering and to graduate engineers. Many universities offer an opportunity to do research in powder metallurgy, or to cooperate in research projects sponsored either by the Government or by private industries.

The majority of the metallurgical societies in this and foreign countries have special committees devoted exclusively to powder-metallurgy matters or hold sessions on the subject at their annual meetings. These programs are increasing in interest and attendance. This cross fertilization of ideas is only another reason why the growth of the science and techniques of powder metals and cermets will continue at an accelerating pace in the next few years.

There is so much to learn, so much to do!

Fig. 5 – Effect of Sintering Time and Temperature on the Microstructure of 4% U, 96% Zr Alloy Compacts. 125 ×



Heat Treating Equipment and Procedures

*By CARL L. IPSEN**

Atmosphere control, induction heating and mechanization have contributed most to improvement of heat treating processes. Future progress is limitless and impossible to predict. (J general)

METAL PROGRESS chose a significant date for its birth. The years immediately following marked a big transition in applied metallurgy. One exemplification is in the field of heat treating equipment and procedures.

Basic developments of that period include generators for producing controlled atmospheres at low cost, gas carburizing furnaces, radiant tubes, reliable mechanized furnaces, and induction heating equipment for surface hardening and billet heating. These devices enabled the metallurgist to put into practical operation many processes previously confined to the laboratory. They have also paved the way for the introduction of such entirely new processes as bright hardening without decarburization, selective hardening, bright annealing, furnace brazing and sintering – to mention only a few of the most important.

It is safe to say that more progress has been made in heat treating during the past 25 years than in all prior time. This takes in a lot, for heat treating is an ancient art.

Controlled atmospheres clearly head the list of important developments. They eliminated the scale and decarburization that had previously plagued all heat treaters. Parts can now be heat treated at high temperature without impairing their bright luster and with accurately controlled surface carbon. The latter is the most important factor in guaranteeing the expected strength of most machine parts.

An epochal step in this field was taken just about the time *Metal Progress* was born. I refer to the development of a practical atmosphere generator to provide cheap sources of suitable gases. As noted in a list of metallurgical milestones published in this magazine ten years ago, two important dates are:

1928

Controlled atmosphere furnace, to minimize scale on steel bars, furnished Timken Roller Bearing Co. by Electric Furnace Co.

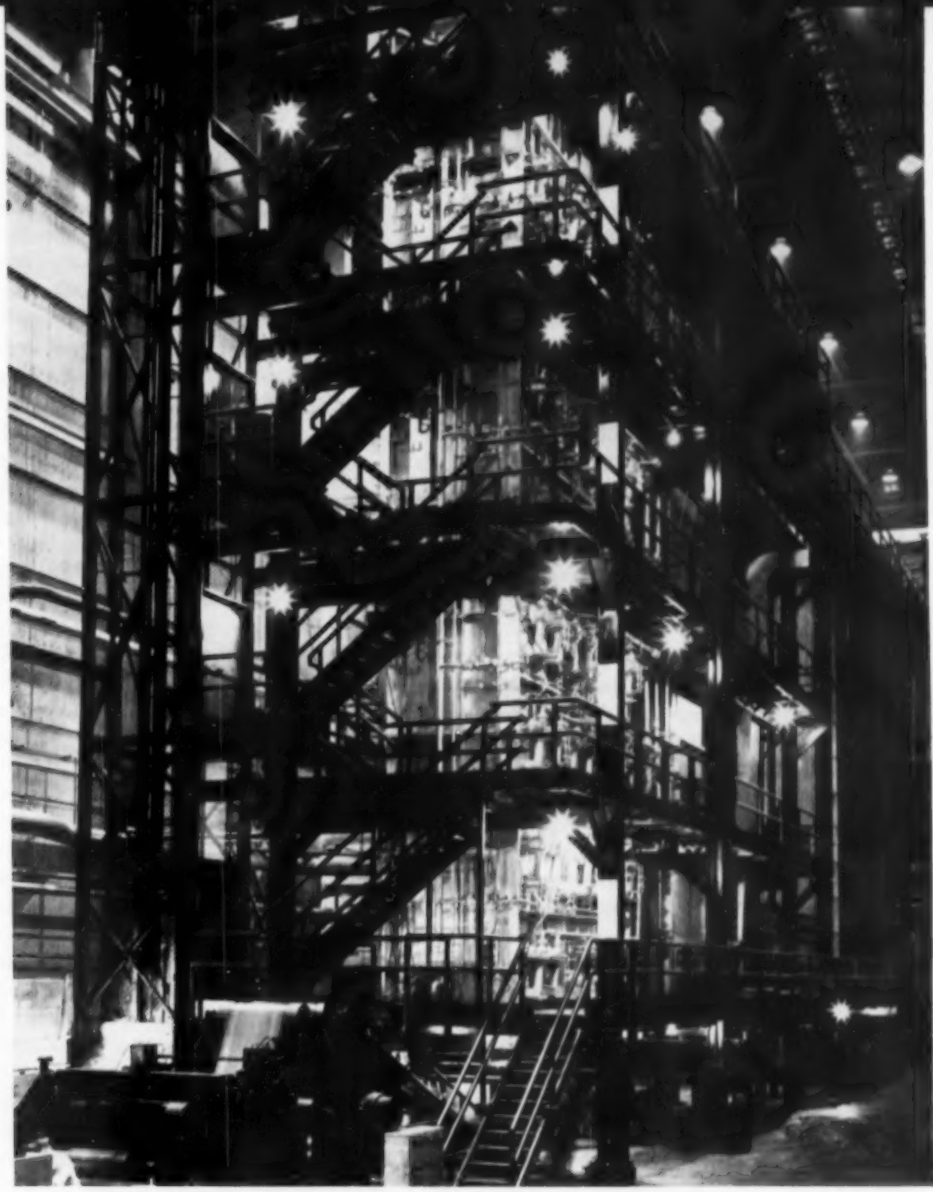
1931

Equipment for continuous bright annealing of steel strip and wire made by Process Engineering & Equipment Corp. of Attleboro, Mass.

The early generators, known as the "exothermic" type, produced a controlled atmosphere by partial combustion of a hydrocarbon gas, leaving unburned hydrogen and carbon monoxide which made the gas highly reducing. Drying by surface condensors, refrigerators, or chemical driers rendered the gas reducing throughout the heat treating temperature range. It thus proved to be the ideal gas for bright annealing most metals and is still widely used for that purpose. But its relatively high percentage of carbon dioxide – a strongly decarburizing gas – made it unsuitable for high-carbon steel.

Two approaches to the development of an atmosphere for high-carbon steel followed closely on the heels of the exothermic generator. In the first, an atmosphere was produced by the partial combustion, in a heated retort full of catalyst, of a hydrocarbon gas with a low proportion of air. Since external heating is required, the term "endothermic gas" naturally follows. The high hydrogen and carbon monoxide and low water vapor and carbon dioxide content of endothermic gas fully met the requirements for heat treating high-carbon steel without decarburization. By regulated additions of methane its "carbon potential" can be controlled over the entire carbon range required for heat treating and for carburiz-

*Executive Vice-President of Industrial Heating Equipment Association, Washington, D. C.



A Continuous Furnace for Bright Annealing of Tin Plate. Annual Capacity, 136,000 tons. Installation at United States Steel's Gary plant

ing steel – that is to say, the gas can be readily adjusted so as to be in equilibrium with the iron-carbon alloy at working temperatures.

The second approach to this problem was to remove the carbon dioxide from an exothermic gas. Passing the gas through an amine solution which absorbs CO_2 did this trick. Since the amine solution can be reactivated by a subsequent heating and cooling cycle, the process is suitable for economical and continuous operation. An atmosphere ranging from almost pure nitrogen to a highly reducing gas can be produced by this method. More recently equipment has been marketed for removing carbon monoxide from the atmosphere while retaining the hydrogen. This versatility has created a much wider field for exothermic generators.

The impact of these controlled-atmosphere developments has indeed been revolutionary. Today most heat treating furnaces are atmosphere-controlled, whereas 20 years ago they were a rarity. This widespread use created a demand for automatic controls, and instrument manufacturers have responded to the call. To mention just one innovation, control instruments are now available that automatically maintain the carbon potential

of a gas within extremely narrow limits. The day of precision heat treatment is at hand.

Gas carburizing cannot be claimed as a development of the past 25 years, for its early uses far antedate that period. Gas carburizing has, however, been adapted to large-scale production use since 1930. Prior to that time most production carburizing was by the pack method. Continuous carburizing was first placed in commercial operation in the United States in 1931 in Chrysler Corp.'s Newcastle plant, using natural gas diluted with partially dried flue gas and equipment manufactured by Surface Combustion Corp. The success of these furnaces and others of the batch type devised during that decade can be attributed not only to superior furnace construction but also – and primarily – to the control of atmospheres whereby carbon potential was regulated by additions of methane to a carrier gas. Batch furnaces were improved by the addition of fans to circulate the carburizing gas rapidly through the work. These improvements have resulted in almost complete abandonment of pack carburizing in favor of the cheaper, more readily controlled gas method – all in the short period of 20 years.

Accurate carbon controls have lent great impetus to homogeneous carburizing, carbon restoration, and carbo-nitriding. Steel mills are now being equipped with carbon restoration furnaces to replace the carbon lost in hot rolling operations. Previously, decarburized surfaces were removed by grinding or machining with much higher cost and much material wasted.

Radiant Tubes – The electric furnace was ideally suited to receive the newly developed protective atmospheres. Not so the fuel-fired furnaces. Large, expensive, troublesome muffles were the only means of shielding the parts being treated from the products of combustion.

The fuel-fired furnace, however, did not have long to wait. The radiant tube was invented in 1933 and installed a year later in a production furnace built for Superior Sheet Steel Co. by Lee Wilson of Cleveland. It has now become the standard equipment for atmosphere-controlled fuel-fired furnaces of all types. Combustion is confined within small-diameter tubes which radiate their heat to the furnace interior. No products of combustion from the heating source enter the working chamber.

Salt Baths – Concurrent with the development of atmosphere furnaces has been the salt bath furnace. Molten salt protects metal from the oxidizing and decarburizing effects of air and also provides extremely rapid heat transfer in heating (or cooling). This latter characteristic of salt baths has been used increasingly during the past few years for cyclic annealing and for martempering and austempering. Rapidly recirculating molten salts have quenching rates suitable for many products without the distortion resulting from more conventional quenching equipment.

Mechanization is not new; there are many good examples of mechanized furnaces installed during the decade preceding 1930. These include pusher, roller-hearth, rotary-hearth, walking-beam and conveyer furnaces. The general acceptance by industry is, however, a feature of the past 25 years – the result of improved and more reliable furnaces, better heat resisting alloys and design of the mechanisms, of a demand by metallurgists for greater precision and operational control, and of the emphasis on cost reduction.

The past ten years have witnessed an almost complete transformation of the market for the once lowly box-type furnace. In its modern version the operator merely places the tray of work in front of the furnace. From then on all operations of charging, heating, quenching and discharge are automatic. Enclosed quench tanks attached to the furnace exit permit the charge to be quenched without even a momentary exposure to air. The parts are delivered from the furnace with their machined surface and luster unimpaired and with uniform hardness.

Furnace copper brazing was invented in 1917 and used sporadically during the 1920's, but commercial operation had to await suitable atmospheres and furnaces. Box-type, mesh-belt, and roller-hearth furnaces working at the high temperatures required for copper brazing are all products of the past quarter-century. Modifications of these furnaces are also used for sintering powder-metal parts.

Advances in annealing of malleable iron castings are equally impressive. Twenty-five years ago the average annealing cycle was 8 to 10 days (*days* is correct!) and the castings had to be packed in sand in heavy annealing boxes to prevent scaling and distortion. Today, continuous and batch-type furnaces with protective atmospheres have cut the annealing time to a small fraction of the pre-1930 rate. No packing material is required. Costs have been reduced and quality of castings improved.

The first continuous strip annealing furnace of the tower type was installed in 1929. It was the forerunner of many continuous annealing furnaces in brass and steel mills. Furnaces are in operation today bright annealing 30 tons of tin-

plate strip per hr. at a speed of 1000 ft. per min. Many similar furnaces are used in conjunction with galvanizing pots to bright anneal and galvanize steel strip continuously.

Induction Heating – Research by Edwin F. Northrup at Princeton University and patents dating back to World War I set the stage for practical surface hardening by high-frequency induction heat in 1929. This was followed in 1935 by the production hardening of crankshaft bearings (at International Harvester's Tractor Works in Chicago using Tocco equipment) and in 1937 an automatic machine was built for hardening camshafts. From these beginnings induction heating has grown into a major industry serving countless applications in surface hardening and selective hardening of machine parts. The extremely high speed of heating, accuracy of control, low operating cost, and adaptability to production-line operations are major advantages that have contributed to this spectacular growth.

Induction equipment for through heating of forging billets received real impetus during World II; several shell plants were so equipped. The method now is widespread. The use of 60-cycle current for heating billets is of more recent origin, but is now frequently found, heating aluminum and magnesium billets for extrusion and forging. Billets are also preheated by 60-cycle current and subsequently heated to forging temperature by a higher frequency.

Research on induction melting of metals in a vacuum dates back to the early 1920's, and the first vacuum pouring furnace, with a capacity of 10 lb. of metal, was developed in 1930. For the next two decades, the interest in vacuum melting was confined to small-scale production of special metals. However, during the past two or three years, the field has broadened to include the vacuum melting of engineering alloy steels in production lots because of the great improvement in fatigue resistance obtainable. Several 1000-lb. furnaces are now in use or under construction.

The Future

In this brief review only a few of the many outstanding accomplishments have been noted. These few do, however, clearly reveal the trend and are evidence that this has been a transition period of revolutionary proportions. Just try to imagine where industry would be today if it had only the tools and procedures for heat treating that were available in 1930!

In the light of this amazing rate of progress, it is hard to make any predictions that won't sound absurdly conservative 10 or 20 years hence. All I can do is to indicate some of the more obvious trends.

Heat treating will be put to many new uses. One of the most promising of these is the heat treating of structural shapes and plate – much larger pieces than are now common. We see the time coming when such structures will be twice as strong or half as heavy as they are now, as the result of heat treatment of proper alloys.

The trend to put heat treating equipment in the production line will continue at an accelerated rate. With the high cost of labor and the need to eliminate human frailties and errors, the day must inevitably come when we shall have veritable push-button control. To meet production-line requirements, furnaces will be designed for greater durability and for easy access of all parts requiring replacement. Controls will be simplified and more reliable. Quick and easy servicing is essential.

Today no furnace operator would consider running a furnace without automatic temperature control. Not so many years ago such controls were a novelty. I forecast a similar trend in the acceptance of carbon potential controls.

Much progress has already been made in the scale-free heating of billets for hot forming. This trend will continue and will include the heating of ingots in the steel mill. Heating may be by induction or by atmosphere-controlled furnaces.

Human comfort in areas adjoining heating equipment will be given more consideration in the future.

New combustion methods and improved refractories will provide higher temperature and more rapid heating.

Distortion of parts during heat treatment will receive more attention. One solution of the problem will be to make more use of martempering and austempering.

No forecast would be complete without mentioning atomic energy. All that can be said now is that it has greatly increased the world's source of heat. How it will be applied to heat treating no one knows. With our present knowledge all we can say is that it is a promising source of electricity.

This is far too modest a forecast. History reveals that with the ever-increasing base of accomplishment, advances are made at an exponential rate. Heat treating will follow this curve and many new and revolutionary equipments and processes will be developed that are still far beyond my present limited vision.

Metallurgical Education, 1955

*By AUSTEN J. SMITH**

Metals engineers are becoming scarcer as industry needs more, yet universities receive fewer qualified candidates. One solution suggested is greater professional consciousness. (A 3)

This birthday issue of *Metal Progress* comes at a very significant period. Over the last 25 years most amazing developments have taken place, opening up fields totally unanticipated in 1930 – uranium alloys, germanium alloys, continuous casting, titanium alloys, and a host of other commercial developments such as brass mills going into the aluminum business. For those concerned with the education and training of the students who are to become the metallurgists of tomorrow, it is high time to take stock.

"Whither?" always brings to mind "Whence?" Metallurgical education has had a quite varied background. The curricula at the several schools make this peculiarly evident. In the older institutions, metallurgical engineering usually developed hand in hand with mining engineering, with particular emphasis on extraction. At such schools, for example, fire assaying was retained in physical metallurgy curricula until quite recent date, and many still require the study of mineralogy. Departments with such background often are found in schools of mineral industries rather than in schools of engineering, as for example, at Pennsylvania State University and the Missouri School of Mines, and extractive metallurgy occupies an important place in the curricula, but is not found at all in others.

It was very natural that study of physical metallurgy commenced early in these schools. The work of such men as Sorby and Heycock and Neville was noted first by those concerned with extractive metallurgy and we find the science advanced rapidly by Howe, Sauveur, Campbell – all associated with departments of mining and metallurgy.

At other institutions teachers of physical chemistry and, as it developed, phase chemistry, began to study metallic systems and introduced courses in metallography. Some of their associates at these institutions were more concerned with industrial chemistry. These fields of metallography and industrial chemistry developed side by side; they were ultimately separated from the science schools and attached to engineering schools as combined departments of chemical and metallurgical engineering. This joint development is evident in the requirement, in many current curricula, of such courses as "Unit Operations". Some schools even retain organic chemistry within the metallurgical curricula.

At a rather early date other engineers, especially mechanical, recognized the need for instruction in the metallic materials of construction, both from the production and application point of view, and service courses were established to fill this need. At the writer's own school, for example, courses in foundry, forge, and heat treat were certainly established by the late 1880's. Where metallurgical engineering departments have had such an origin, greater stress would be expected on drawing, mechanics, and machine design than in schools with a different history.

Diverse Curricula Offered

With this extremely varied background there is small wonder that little conformity exists in the curricula offered. Each must be considered defensible from its own point of view. Nevertheless, this leaves a rather unsatisfactory state of affairs. The whole situation is further complicated by present trends in graduate instruction and

*Head, Department of Metallurgical Engineering, Michigan State University, East Lansing, Mich. The author has discussed these problems with many people but is especially indebted to Prof. Amos Shaler of Pennsylvania State University and Prof. R. Schuhmann, Jr., of Purdue University, and has freely adapted a number of their ideas.

research. For a number of reasons – an important one being the terms of sponsorship for supported research – the greatest emphasis has been placed on fundamental investigation in the fields of metal physics and metal chemistry. So far has this gone that able graduates in physics and chemistry from liberal arts colleges have become equally, and at times, more welcome for doctorate metallurgical programs than metallurgical graduates! While instruction is still included under the term "metallurgy," it should be understood that "metal science" is the more exact term, for metallurgy carries, by definition, the principles of usefulness, while economics play little part in these research patterns. It is not intended to imply that such research is not important, but the point is made to show the disparity of viewpoint in undergraduate and graduate instruction. The teaching staff must be selected from those capable of directing such research programs; the small enrollments of undergraduates will support no other kind.

It is often stated that metallurgy and metallurgical engineering are synonymous. At present this is scarcely true. A certain pattern has developed in engineering curricula in which, for certain courses, there is a general conformity over all the fields. The basic courses generally include physics, chemistry, and mathematics through integral calculus, statics, dynamics, strength of materials, thermodynamics, heat transfer, and differential equations. On these foundation stones the specialized curricula are to be built. In its attempt to arrive at a quantitative evaluation of engineering curricula the Engineers Council for Professional Development has taken cognizance of these building stones, and most registration examinations set up by state boards for engineers-in-training expect a certain competence in these fields. Not too many metallurgical engineering curricula cover all of them. In some accredited curricula, mechanics and strength of materials are not offered until the senior year, when they can hardly be considered as "building stones". At the writer's own school dynamics and differential equations are not required and the department has been very much in a quandary over what sort and how much thermodynamics to include; this has been true at a number of other institutions. For the average undergraduate these courses are largely window dressing, to be promptly forgotten on graduation. However, our future technological development will call for increasing application in these areas, and first consideration must go to those students who must be depended on to advance our state of knowledge.

Recently, a recommended pattern has been circulated by the National Council of State Board Engineering Examiners for the examination of Engineer-in-Training (recent B.S. or equivalent degree). It pays no heed to the particular branch of engineering in which the student has specialized. It expects that all engineers will have taken certain basic courses and in these the Engineer-in-Training should demonstrate proficiency. Questions must be answered in every area. Among others, we find such topics as engineering economics and fluid mechanics – subjects that do not usually appear in metallurgical engineering curricula. Indeed, few metallurgical graduates would be prepared for such examination. It is probable that the mining engineers, the chemical engineers, and even the electrical engineers would find themselves in the same predicament.

Among the areas in this recommended pattern of examination, the proper usage of the engineering materials of construction does not appear. At this many metallurgists will shudder, especially those who have spent a large portion of their working hours pulling the hot chestnuts of the design engineer out of the fire. So it appears that the metallurgical engineers (as well as mining, chemical and electrical) in their self-exclusive groups have failed by default in taking a positive position in the activities of the American Society for Engineering Education, the Engineers Council for Professional Development and the National Council of State Board Engineering Examiners. Unfortunately, it may be found that a pattern once established is very difficult to alter.

Low Enrollment in Metallurgy

The low enrollment of students in metallurgy and metallurgical engineering in this country has been considered very seriously by the American Society for Metals, as well as by educational institutions and many employers. In this nation, whose whole position of prosperity has been virtually built on iron and steel and related phases of the metalworking industry, the situation is, speaking bluntly, appalling. The number of graduates in metallurgy is at the bottom of the list, and while the other engineering fields are increasing, metallurgy is not keeping step. According to a report of the Engineers Joint Council, out of a total of some 19,000 June 1955 graduates in all engineering only 486 were enrolled in metallurgy or metallurgical engineering. This handful of young men is supposed to

provide the brains and skill needed by our greatest industry. 486!

Blame for this low enrollment in metallurgy is often placed on ignorance; the secondary school graduate does not know anything about the field and when the opportunities dawn upon him in college years, it is too late to transfer. (However, there is little compunction on the part of employers to transferring other engineers into metallurgical work!) The explanation is well taken; the secondary school graduate, as a rule, has never heard of metallurgy, nor has the man on the street.

Whose fault is it?

It might very well be our own. The metallurgist, more often than not, fancies himself as a scientist, particularly when influenced by our graduate research programs. Yet seldom is his bachelor's degree received from a science school. On the other hand, the curriculum patterns are not such that he can take his place with other engineers.

What then is to be offered the incoming freshman of this science which is not science, or engineering which is not engineering? The secondary school graduate might very well wonder what place he will occupy in the scheme of things if he elects this field which is so lacking in professional consciousness.

More and more attention is being paid to these problems, in industry, in society activities and in education. Especially to the educational institutions, with present low enrollments, is the matter of great concern. Probably it is of equal concern to employers, although only a few have shown any inclination to study the problem.

A number of curricula have been described in recent literature, and the trend is significant. Supported by the sciences, we must define our own fields of engineering and build on them. Especially worthy of attention is a recent article by Prof. R. Schuhmann, Jr., of Purdue University, published in *Journal of Metals* for May 1955. Here a positive attempt is made to define metallurgical engineering and to coordinate the basic courses so as to lead to the graduation of a professional engineer. To Professor Schuhmann, engineering comes first.

Not everyone will agree with the program proposed by him. The general pattern can be fairly readily accepted. The disagreement will be over the details, one of which is that the competence required is a little above that possessed by the average student.

What Is Expected of a Metallurgist?

It is in order to ask, "What is expected of a metallurgical engineer?" A rather close parallel may be drawn with the chemical engineer; one deals with metallic materials of construction, the other with nonmetallic (construction here being used in a very broad sense). The chemical engineer, responsible for process control, is also responsible for the design of the process equipment. (The materials in process fall in large part into the hands of the industrial chemist.) In metallurgical engineering, on the contrary, great attention is paid to the material in process, and design of process equipment has passed by default to the mechanical engineer. An examination of the backgrounds of the membership of the Association of Iron and Steel Engineers is particularly illuminating in this respect.

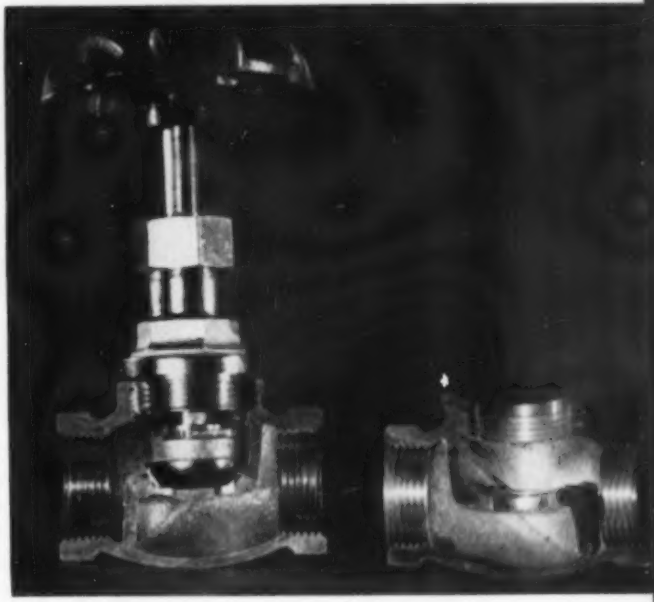
Again we must return to our question: Whither? We have a priceless heritage in our techniques of metal production and metalworking. It is our solemn obligation to attract the finest talent and ingenuity in our country to this field, on which the prosperity of our country rests. If metallurgy is to move into the realm of pure science, who is to be responsible for the engineering phases? Who is to change steelmaking from a batch to a continuous process; to bypass the ingot for continuous casting? It is not intended to imply that metal science is not of tremendous importance, but metals engineering must be elevated to equal importance.

Many in industry believe that the educational institutions go too far in endeavoring to turn out all research men. It is, perhaps, not realized that this erects a difficult problem for the educator. In educational circles it is fully realized that only 10 to 15% of the graduates are suited by scholarship and by temperament for applied research, some 5 to 10% for fundamental research. As reported by Professor Bever of M.I.T., in last month's *Metal Progress*, only 51 doctorates were awarded in metallurgy in the academic year 1953-1954. From this small group is to come the new blood for fundamemntal research and also the new blood for our educational programs.

Obviously, the number is nowhere near sufficient to take care of our present needs. Consequently, many employers who are outbid for the services of competent research people must make the best out of the graduates with a bachelor's degree. Many of these are not fitted

(Continued on page 186)

Cross Section of Bronze Valve "Electroless" Plated With Nickel



Progress in Metal Cleaning and Finishing

*By ABNER BRENNER**

Electroplating of elements from aqueous solutions has about reached its limit; future developments will include wider use of alloy deposition and nonaqueous plating solutions. (L general)

THE YEAR 1955 which *Metal Progress* is celebrating as its 25th anniversary has a similiar significance for the author of this article since he entered the field of electrodeposition just 25 years ago. Any review, however, must be made in the knowledge that the relative importance of events is often a matter of opinion, colored by an individual's specific line of work and contacts during that period. For example, a worker in the field of metal cleaning would view the advances in the metal finishing field from a different angle from one who has worked solely in the field of electrodeposition.

With this limitation in mind, let it also be stated that any prediction of future advances – unless the prediction is to be pure fancy – must be based on history. Expectations must be extrapolated from the past into the future. This is a sound approach because the germ of an idea exists long before it is incubated. In fact, to develop an extrapolation formula, the occurrences of the past 25 years will be prefaced by a short summary of the history of our art before 1930.

Progress in electroplating during the first quarter of this century was reviewed by George B. Hogaboom in *Transactions* of the American Electrochemical Society in 1927. This gives the impression that, with the exception of chromium and cadmium plating, no new or unusual plating processes were devised. The period is characterized by an awakening of the electroplaters to the existence of modern engineering technology and by a growing awareness of the value of scientific methods. The four technical societies

*Chief, Electrodeposition Section, Div. of Chemistry, National Bureau of Standards, Washington, D.C.

which deal with electroplating were founded – the Electrochemical Society, American Electroplaters' Society, and the two British societies, the Electrodepositor's Technical Society (now called the Institute of Metal Finishing) and the Faraday Society. Modern methods of analysis and control rescued the operation of plating solutions from the realm of black magic. The scientist began to examine the structure of deposits and some of the factors and phenomena which affect or accompany plating processes, such as polarization and current distribution.

During the next 25-year period, from 1930 to 1955, the metal-finishing industry made full use of many modern scientific tools and engineering advances, so that it attained mature stature as a manufacturing industry. Although this growth was not attended by any revolutionary changes, a number of new processes came into being. Recent history of commercial metal finishing has been characterized by intensive exploitation of processes known or discovered before 1930, but very little of a new or basic character has altered the earlier pattern.

Now to develop this matter in some detail.

Improvements in Plating Processes

Bright plating processes are now operating with a number of metals, including nickel, copper, zinc, cadmium, silver, gold, rhodium, tin and cobalt-nickel alloy. Some rather unusual inorganic salts, added to the baths, promote plating at higher current densities or increase brightness. Among these are the sulphamates, fluoborates and pyrophosphates. None of this is revolutionary, but each item played a part in advancing the art.

No new metals were electroplated commercialy during the last 25 years. This is not due to lack of research but to a natural limitation, namely, that all the metals capable of being deposited from aqueous solution in the pure state had been deposited already.

Advanced engineering has perfected automatic plating and the continuous plating of strip and wire to a point undreamed of before 1930. The large installations in the steel mills for continuous plating of steel strip with tin and of wire with zinc, and the large automatic systems used by the automotive companies, are the most striking examples of mechanization in the metal-finishing industry.

The use of electroplating for engineering applications took a leap forward. Prior to 1930, electroplating was mainly for decoration and protection, but the growth of technology, particularly in the aircraft and electronics industries, brought many problems of a mechanical nature which often were solved by plating. Among these are antifriction bearings, hardened surfaces to resist wear, prevention of oxidation, reflective surfaces for light and radiant heat, porous barriers, electroforming of objects, and the joining of metal surfaces by plating across their junction.

Automatic Plating Machine Can Be Operated Entirely From a Central Board, Where Time, Current and Voltage for Each Stage Can be Controlled. (Courtesy of International Nickel Co.)

Plating on nonconductors, particularly plastics, also has been commercially exploited. In this activity, again, we find no new fundamental developments – the methods were already known. The growth of this branch of plating can be attributed to the great increase in the production and use of plastics.

The shortage of nickel during and since World War II has focused attention on this metal. Among the proposed substitutes are antimony, white brass, bronze, and, more recently, iron-zinc alloys overlaid by chromium. However, none have the combination of useful properties possessed by nickel.

Another characteristic of the last quarter-century was a realization of the value of testing and the need for specifications. These concepts certainly are not new, but the time was ripe. The chief impetus came from the automotive industry and the Federal Government. Both were such large purchasers that they could insist that the platers be responsible for the quality of their product.

Before useful specifications could be written, some information about the service life of the coatings was necessary. This was first studied by atmospheric exposure tests started by the American Electroplaters' Society in 1930 and lasting until about 1940. Subsequently, similar

studies were made by the American Society for Testing Materials and other agencies. *Thickness* of plate was found to be the most important criterion. Use of the resulting specifications is voluntary; unfortunately, not many organizations have adopted them. One reason is that many plating plants are an adjunct of large manufacturing organizations, and the latter apparently feel that compliance with a uniform standard is less necessary for their own work than for the product obtained from job platers. It seems odd that even the silver-plating industry has no mandatory specification for coating thickness although there are some voluntary standards, albeit not too well defined.

Along with interest in specifications has come the perfection of nondestructive tests for plating thickness. Magnetic gages for measuring the coatings on steel were followed by electronic gages, based on "skin effect"; they are useful whenever coating and base metal differ in electrical conductivity.

New Ideas in Metal Finishing

Evidence that the metal-finishing industry has developed from an art to a technology is given by the considerable increase in research. All of the modern scientific tools and techniques have been used, including the microscope, electron microscope, X-ray diffraction, electron diffraction, and radioactivity. This attitude concerning research was first shown by the establishment of the American Electroplaters' Society's research program about 25 years ago; 15 projects have so far been carried out. The properties of several electrodeposited metals have also been studied, although not exhaustively.

A number of new ideas have appeared in the metal-finishing field, but none have grown into large commercial operations. Electropolishing thus far is mainly used for stainless steel and aluminum, although the prospective supply of metals and alloys with fewer inclusions may extend its use. Chemical polishing solutions have also come to the fore, although they do not brighten to the same extent as electropolishing. Periodic reverse plating, applicable to a limited number of plating baths, is finding increasing use, but not as rapidly as anticipated.

Many alloys were electrodeposited successfully during the 1930-1955 period. The British Tin Research Institute has been especially active in devising means for electrodepositing alloys such as nickel-tin, tin-zinc, and speculum metal. It seems likely that the tin-zinc plate alloys will slowly widen in use. Other alloys which have potential uses because of their hardness and corrosion resistance are the phosphorus and the tungsten alloys of nickel and cobalt. Bright cobalt-nickel alloys were exploited, but mainly as a decorative finish, but both of these metals have other more essential uses. Lead-tin, copper-lead and silver-lead alloys were investigated for use as bearing metals, but only lead-tin has been utilized to any extent. Altogether about 100 different alloys can now be electrodeposited; many should find special applications that cannot be satisfied by single metals.

One new process which appears to be growing rapidly in importance is electroless plating. It fills special needs, such as uniformity of coating and complete coverage of recesses, which cannot be duplicated by ordinary nickel plating. As the control and operation of this type of bath becomes better known, wider application should follow. Probably 50 plating shops are now using

it on a small scale, and there are a few large installations.

The phenomenon of micro-throwing power or leveling action of plating was discovered, but an explanation of this curious phenomenon has not been found. It is used to cover irregularities of the base metal. Brightness and leveling action do not necessarily go together.

Several other unconventional methods of producing metallic coatings have been studied but have not come into commercial use, such as the thermal decomposition of the carbonyls of chromium, tungsten, molybdenum or nickel. Thermal reduction, which involves the reaction of a metal halide with hydrogen on the surface of an object, also has possibilities for special applications but no great potential for future use, except for specialties where tungsten, tantalum, and molybdenum coatings cannot be readily obtained by other means.

There is a need for adherent coatings upon titanium, zirconium, beryllium, molybdenum, tungsten, and aluminum. Several satisfactory methods of plating on aluminum have been worked out. Procedures are available for depositing nickel and chromium on the other metals mentioned, but they are not always convenient nor consistently satisfactory.

Chemical conversion coatings, principally on zinc, cadmium and magnesium, have very good corrosion resistance. Chromate solutions are quite useful for zinc and cadmium. Immersion dips were also developed for magnesium, but the best coatings were formed with electrolytic treatments, such as the "HAE" process or the low-voltage chromate process, both of which form oxide coatings on magnesium with good resistance to salt spray.

Deposition of metals from nonaqueous mediums – either fused salts or organic solutions – is in the development stage. Such coatings of molybdenum and titanium from fused salts have not yet been commercialized. Organic solutions for deposition of aluminum, beryllium and germanium must be protected from the moisture of the air and are inflammable – hence are limited to very special applications. An organic bath for hydride-aluminum plating yields pure, ductile deposits several hundredths of an inch thick, but has found no commercial utilization up to the present.

For maintenance and control of solutions, we now have continuous filtration, use of activated carbon and filter aids, and good purification methods, particularly for nickel baths.

New Cleaning Procedures

Advances in cleaning procedures have paralleled plating progress. While the same conventional chemicals – sodium hydroxide, carbonate, and trisodium phosphate – remained the basis of most cleaners, many additions were made to secure special advantages. Among these are synthetic detergents, polyphosphates, silicates, and sequestering agents. In fact, the manufacture of cleaners has become the most competitive area of the metal-finishing industry. Among the newer methods may be mentioned the use of vapor degreasers, emulsion cleaners, diphase cleaners, the abrasive wet blast, anodic instead of cathodic electrolytic cleaning, and ultrasonic methods.

In metal polishing no major advances stand out, but there were many improvements in the design of buffs and in the methods of feeding the abrasive to the wheel. The abrasive belt was something of an innovation. Probably the most spectacular advance, as viewed by the layman, was the automatic polishing and buffing machines.

The growth of the plastics industry presented a wide variety of new materials of construction, not only for tanks and linings, but also for ducts, hoods and piping formerly limited to steel, glass, wood, or hard rubber.

Waste Disposal

The great industrial development of the last two decades has raised a new and serious problem for the plating industry. Laws in many states now restrict the disposal of wastes in the waterways. A comprehensive study of the situation is being made by the Ohio River Valley Water Sanitation Commission and a study of waste treatment has been started by the American Electroplaters' Society. In the not too distant future a plating establishment will have to operate a waste disposal plant as part of its manufacturing activities. The resulting increase in production costs can be offset in part by recovery of metals formerly lost or by more efficient operation of the plating plant.

Hydrogen embrittlement of plated parts for aircraft has been extensively studied, leading to a rather confused picture. Reliable methods must yet be developed for measuring embrittlement as well as for its relief or elimination. In the last two years the subject came to the fore again, with the introduction of steels of 250,000-psi. ultimate strength into aircraft landing gears.

Things to Come

The great advances in our industry during the past 25 years may be attributed to external factors, since the metal-finishing industry itself tends to be rather conservative. The stimulus was provided by the demands of World War II, the subsequent Korean War and the "cold war". Other important factors were the growth of the atomic energy program and of the electronic and aircraft industries. Plating was required for many new engineering applications involving such items as gun barrels, bearings, pipe, diffusion barriers for gas, electron accelerators, and waveguides. These applications of electrodeposition were not engendered without research.

Nevertheless, research has been largely devoted to special problems, details of practice or to proprietary plating processes. Of the many publications only a small number deal with exploratory or basic research. Even in the research program of the American Electroplaters' Society relatively few of the projects were fundamental in nature. The supply houses expended their research effort on improving their proprietary processes. The automotive industries, which use 65% of the plating in the nation, have done relatively little research in metal finishing (or at least have published very little). The largest support for both basic and practical electrodeposition research comes from the Government in its various departments of defense. One reason for this situation is that so many metal-finishing operations are of the "captive" type — a minor adjunct to large-scale manufacturing operations — rather than independent plants of any considerable size and financial resource.

Having in view the advances of the past 25 years we can venture a few predictions. As long as the cold war persists, the Federal Government will continue to pour large sums of money into research, mainly through the Department of Defense and the Atomic Energy Commission. This will continually increase the tempo of research in the metal-finishing industry; its progress will be faster during the near future than ever before. More specifically, the requirements of the aircraft industry, the reactor program, new types of weapons, and the electronic industry, will require new developments in metal finishing. Thus growth will be in the scientific and engineering applications of metal finishing, not in the decorative field.

The status of nickel deserves special comment, since it is our most important metal. It may surprise the plater to know that the forecast is one of surplus, not of shortage. The present shortage is due to stockpiling under a program which will be completed about 1959. The nickel then available in this country annually will be of the order of 330,000,000 lb. — almost twice the present consumption for peacetime uses. Although stockpiling has curtailed plating operations, it will have a long-range beneficial effect, since it has resulted in more mine production, and the stockpile itself will serve as ballast to prevent recurrence of a severe shortage for essential uses. There is no foreseeable exhaustion of the supply of ore in the earth's crust.

In view of these facts a considerable growth should take place in nickel plating, which may be spearheaded by new uses — for example, the coating of steel containers with nickel instead of tin, or the direct deposition of nickel alloys.

In the field of metal cleaning, the use of electrolytic processes, either anodic or cathodic, will gradually be eliminated wherever it contaminates the metal surface. Mechanical methods utilizing detergent solutions will be more generally adopted. It is possible that the abrasive wet blast may be adapted to continuous or automatic plating processes and the ultrasonic methods may become less costly.

Aqueous plating of individual metals has about reached its full development. No additional metals are likely to be added to the present list. The field of brighteners and of different salts for plating baths has also been fairly well exploited. The main advance in aqueous plating will be in the direction of electrodeposited alloys for special engineering purposes. These applications will be directed by technically trained staffs, and the job plater as we now know him will not participate widely. Electroless nickel plating will increase as further research points the way to consistent deposits of uniformly low porosity, and as the cost of the basic chemicals is reduced. New methods of depositing metals or alloys by chemical means will be discovered, not necessarily based on the hypophosphites.

The deposition of metals from nonaqueous mediums is in the investigational stage and is not receiving the support it deserves. However, after a few applications are found, development will doubtless accelerate. It will not take the place of aqueous plating processes but supplement them for special engineering applications which warrant the added expense. Here again, only the technically operated plating

(Continued on p. 192)

Stainless and Heat Resistant Alloys

*By V. N. KRIVOBOK and E. N. SKINNER**

Our best alloys devised in the last 25 years appear to be an "over-aged" dispersion of hard particles in a strong, oxidation resistant matrix. Better alloys may be formulated when we know more about why such aggregates tick. (SS, SG-g,h)

In June 1931, when *Metal Progress* was only a year old, the American Society for Testing Materials conducted a symposium on the effect of temperature on the properties of metals, which was intended to represent the status of our knowledge at that time. It is a handy datum for us in this attempt to appraise a quarter-century of progress in the field of high-temperature alloys, since it brings clearly to mind the situation existing then, not so long ago, yet whose details could not be clearly remembered.

In the early 1930's, the metallurgist concerned with heat resistant alloys led a relatively complacent life; metallurgical developments seemed comfortably in advance of the design engineer's requirements. If one material were not satisfactory, another, usually somewhat more highly alloyed, could be taken from the shelf, dusted off, and offered as a reliable though somewhat more expensive solution to the problem. In a sense, the ability to obtain trouble-free performance at high temperatures was a function of how much the user was prepared to spend.

The passing years have not been overly kind to the peace of mind of the high-temperature metallurgist. While notable advances have certainly been made in his field, they have not been able to keep pace with requirements of the designers who look upon higher and higher temperatures as an attractive means of obtaining increased efficiencies or greater production yields. Our metallurgist, perhaps due to a reputation gained in earlier successes, now frequently finds himself confronted with problems involving temperatures and stresses and even little-understood corrosive environments that would have been considered fantastic in the not-so-distant past. The general attitude is not "How much will it cost?" but "How long will the best obtainable alloy last?"

This trend toward higher-temperature service has, of course, accounted for a good deal of our technological progress in the past few decades; understandably, its impact upon metallurgical research and development has been profound.

In response to the Editor's invitation to contribute to this anniversary issue, we have given much thought to the best method by which to illustrate the progress made in the metallurgy of alloys for high-temperature service, for indeed astonishing strides have been made in studies of fundamental nature, in metals of greatly improved mechanical properties, and in the availability of new alloys in commercial quantities and shapes. Some new and basic concepts of alloying and heat treating have emerged from extensive testing programs of materials and the effect of processing variables. (Much high-temperature research has been in connection with various classified projects, and its achievements cannot yet be disclosed.) For the most part, investigations have been carried out, not

*Development and Research Division, International Nickel Co., Inc., New York.

by the leisurely process of evolution, but under the accelerating influence of urgency – a need for a better alloy for some device either already in existence or at least on the drawing board.

Methods of Evaluation

Time is one of the important parameters affecting the behavior of metals at elevated temperature. Time is a factor of at least equal importance in high-temperature tests. For many applications, the attitude has been that there is no time to wait for better alloys to be devised, tested, and produced on a commercial scale. Perhaps for this reason it has been stated that few new developments in alloys for jet engines and gas turbines have occurred within the past four or five years; most research effort has been directed toward refinement and broader understanding of the factors affecting the properties of existing alloys rather than toward the development of entirely new compositions.

There is a multitude of data on high-temperature alloys describing chemical compositions and mechanical properties as determined by assorted test procedures and after a variety of treatments, and after studying these data one is left with the impression that it is difficult if not impossible to evaluate the strength of these materials in terms of a common and meaningful yardstick. On reflection, this is not surprising. The particular criterion of strength that one favors will depend upon the circumstances under which the alloy is to be used. Thus, in the choice of a metal for steam turbine blading, stresses that will result in the low creep rate of 0.01% in 1000 hr. and in rupture at 100,000 hr. are of interest. In missiles, the total life may be a few minutes.

One hundred thousand hours, roughly 11½ years, is an exasperating length of time. Even a more important factor is this: Many alloys for high-temperature service are complex in their compositions and also in the metallurgical changes resulting from temperature, time, and (possibly) stress. These alloys reluctantly achieve phase equilibrium, even at a given high temperature. Time-induced changes in the nature of co-existing phases (the well-known sigma Ni-Cr phase, for example) or in the dispersion and sizes of particles (over-aging would be a familiar case) affect the properties. One might rightfully point out that in some such methods of testing (as for long-time creep or rupture), we try to measure *changing* properties! These facts should explain why attempts at substituting formulas (for extrapolation from short to long times) for actual tests have not been widely adopted except as a possible short cut for sorting out the interesting from the hopeless combinations. Incidentally, it also explains why so many alloys remain in the "experimental" category for so long.

In jet engine blading, where the designed life may be 500 to 1000 hr., the important properties are creep and rupture, as well as total strain versus time, rupture ductility with and without the stress-concentrating effect of notches, and fatigue. Here the time factor is within experimental limits and the evaluation of alloys becomes easier.

Generally, the standardized tensile test, even when performed at the working temperature, is not considered adequate to supply necessary data for design purposes. In the rotors of the just-mentioned engines, where temperatures are lower than the blades, the short-time tensile yield strength may be given great weight. An extreme case of a special test considered useful is found in certain missile components in which the stress to produce rupture is reached in a matter of a few minutes or even less; for some purposes the designer wishes to know the short-time ultimate tensile strength at fixed or at rapidly increasing temperatures and loads.

Clearly, there is no simple means of comparing, just for example, one metallic alloy which is to have a low rate of creep at 1100° F. with another which is heated rapidly up to 1800° F. and then cools as quickly. Thus the service and the test should be intimately connected. An intelligent evaluation of the alloys should be based on the tests which are most likely to be affected by the time element as well as the other specific requirements of service.

In our appraisal of changes and progress, we have followed this general principle, and have elected to describe and discuss improvements within several classes of alloys in terms of an appropriate basis of strength that will reflect the type of service for which each class is generally used.

Chromium-Nickel Steels (Iron-Base)

Starting with the original analysis of approximately 18% chromium and 8% nickel, this group of alloys has been changed in composition considerably in order to improve the mechanical properties – either increasing the chromium and nickel contents or adding other elements, or both. Some of the alloys date back more than 25 years; for example, properties of such well-

known austenitic steels as 25-20 Cr-Ni and 15-35 Cr-Ni are described in the 1931 A.S.T.M. symposium. While stronger than the ferritic grades, the hot strength of these simple ternary steels is not particularly sensitive to variations in nickel and chromium contents (providing the alloy remains austenitic) nor is this strength much affected by the presence of small amounts of titanium or columbium. On the other hand, the effectiveness of molybdenum (as in A.I.S.I. Type 316) is considerable and places this steel foremost in strength among a group of so-called conventional stainless steels.

Progress in improving the high-temperature mechanical properties of the original steels (shown in Group 1 of Table I in the Data Sheet, p. 120-B) has been largely effected by additions of supplementary elements, principally nitrogen, molybdenum, tungsten, titanium, cobalt, and columbium. With these additions, the chromium and nickel are adjusted so the structure remains a reasonably stable austenite in which are dispersed refractory carbides or intermetallic compounds (or both) which help resist deformation by creep. These alloys are not truly age hardenable, but must depend for their strength upon strain hardening at elevated temperatures, usually up to about 1350° F. While the basic principles underlying this "hot-cold" work are still not well understood, the general effect appears to be one of imparting a beneficial type of residual stress, coupled with an optimum arrangement of dispersoid phases throughout the structure.

The "characteristic rupture strengths" listed for 1200 and 1500° F. are included in Table I merely as an illustration of the degree of strengthening being achieved through further alloying and heat treatment. It is to be clearly understood that results of individual tests may deviate very considerably from "characteristic" values, unless details of processing (hot-cold working), annealing temperatures (grain size), stress-relieving or aging (dispersion of phases) are carefully controlled and standardized. Creep rates may differ as much as ten-fold (some claim even higher), depending on the details of heat treatment. It is not an idle assertion that much work needs to be done if we are to understand and classify the effects of the above-described variables.

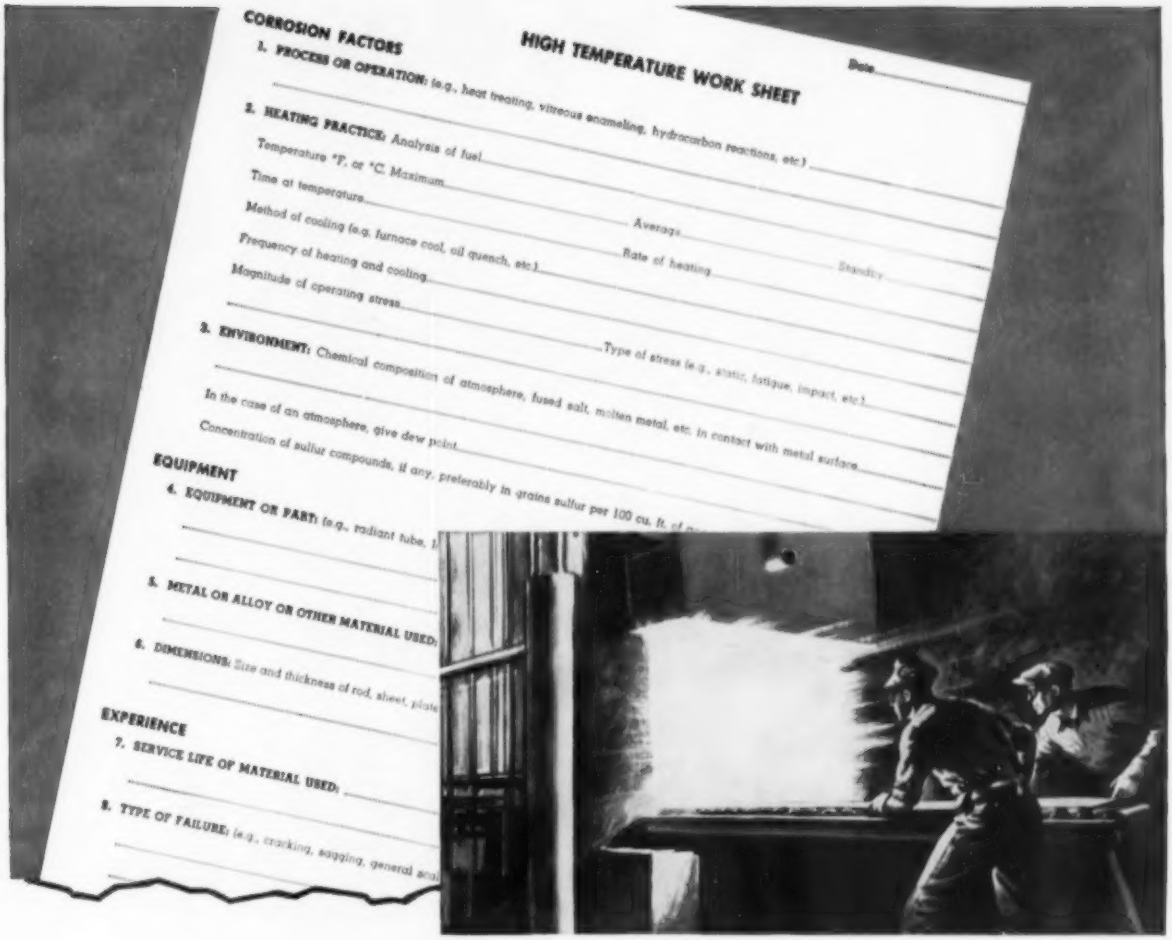
In Group 2 of Table I are listed a number of chromium-nickel steels which are "accepted" in the sense that they have been and are produced in commercial quantities and employed for specific services in which their satisfactory performance has been established. Other alloys, allied to those in this group by virtue of composition and properties, are not included because they have not yet attained commercial use, for various reasons.

These compositions provide a useful class of engineering materials for highly stressed applications within a temperature range of 1200 to 1500° F., and display strengths considerably above those of the conventional austenitic chromium-nickel-iron alloys already known in 1931 and still in wide use in 1955. Whereas the characteristic rupture strengths of conventional 18-8 are on the order of 25, 16, 8, 4 (100 hr. at 1200°, 1000 hr. at 1200°, 100 hr. at 1500° and 1000 hr. at 1500° respectively), and addition of 2½% molybdenum to a basic 18-12 Cr-Ni analysis had increased these figures to 32, 24, 8, 6, further small additions of tungsten, columbium and tantalum make a further notable increase in characteristic rupture strengths.

Nickel-Base Alloys

Together with such noteworthy progress in improving the high-temperaturue mechanical properties of the iron-base alloys, a comparable and simultaneous effort was made to achieve the same result in the few heat resisting compositions of predominantly nickel base (or at least containing quite substantial amounts of nickel) that were in use in the 1930's. Only a handful of these alloys were known to industry 15 or 20 years ago; because of relatively higher cost, their use was restricted to applications requiring special physical or corrosion resisting characteristics. The wrought alloy highest in nickel was the 80-20 Ni-Cr composition, well known as heater elements (electric resistors). Inconel, an 80% nickel, 14% chromium, 6% iron alloy, made by adding ferrochromium to nickel, had been offered in 1932 to the dairy industry for its resistance to corrosion by milk. Hastelloy A and B, containing quite large amounts of molybdenum, were used exclusively for their resistance to highly corrosive chemicals.

The strength of these plain high-nickel alloys at elevated temperatures was essentially of the same order as that of the simple ternary austenitic steels. Their unexampled stability at high temperature led metallurgists, with the advent of the jet engine, to use the compositions shown in Group 1 of Table II as starting points from which a series of high-strength nickel-base alloys was developed. *(Continued beyond insert)*



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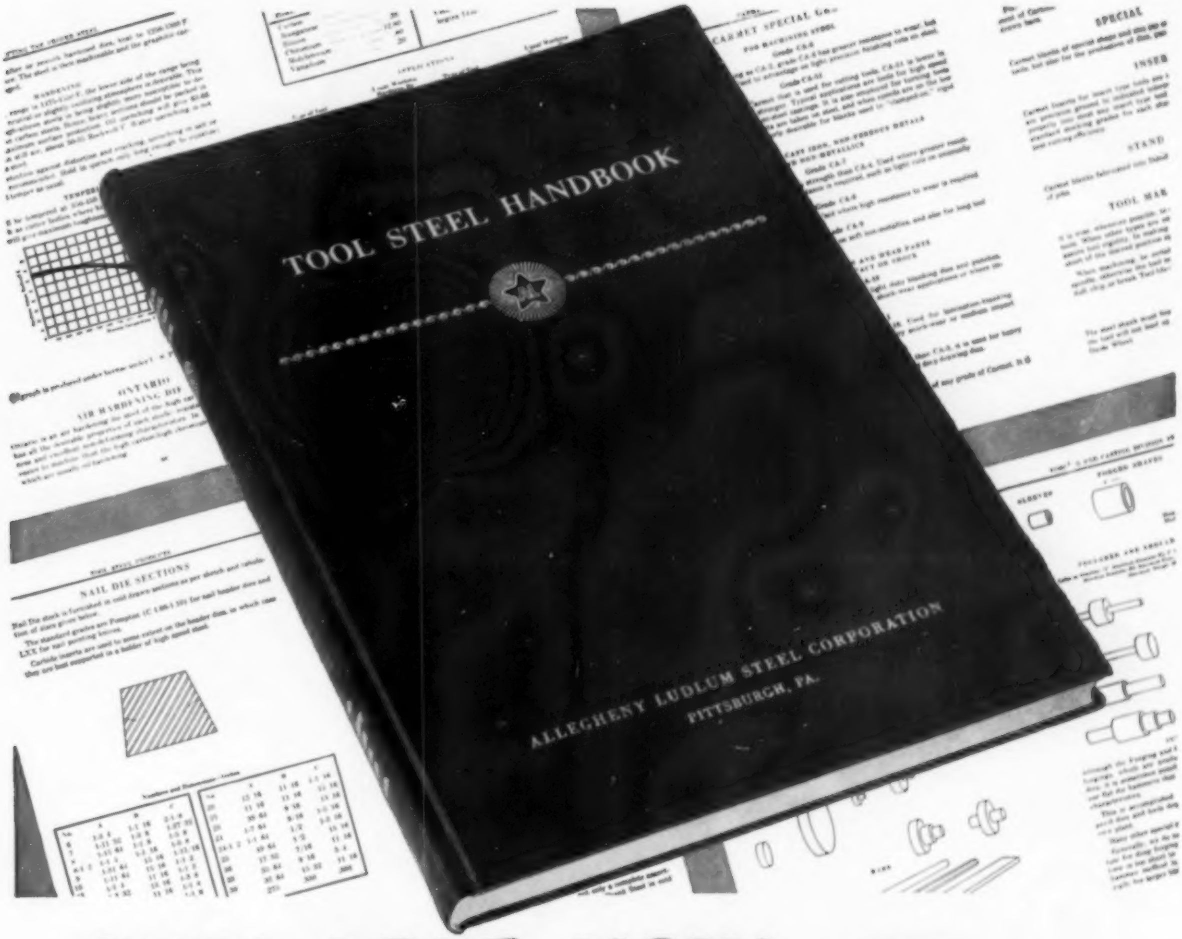
Composition and Strength of Heat Resisting Alloys

Compiled by V. N. Krivobok and E. N. Skinner

Alloy	Nominal Chemical Composition, per cent													Characteristic Rupture Strength, 1000 psi.			
														1200° F.		1500° F.	
	C	Cr	Ni	Mn	Si	Co	Mo	W	Cb + Ta	Ti	Al	Fe	Others	100 Hr.	1000 Hr.	100 Hr.	1000 Hr.
Table I, Group 1—Austenitic Chromium-Nickel Steels																	
A.I.S.I. 304	<0.08	18-20	8-12	<2.0	<1.0	—	—	—	>10C	—	—	Bal.	—	22.5	16.0	6.5	4.0
A.I.S.I. 347	<0.08	17-19	9-13	<2.0	<1.0	—	—	—	—	>5C	—	Bal.	—	27.5	22.0	8.0	4.0
A.I.S.I. 321	<0.08	17-19	9-12	<2.0	<1.0	—	—	—	—	—	—	Bal.	—	28.0	18.0	7.0	4.0
A.I.S.I. 316	<0.08	16-18	10-14	<2.0	<1.0	—	2-3	—	—	—	—	Bal.	—	32.5	23.8	8.3	5.8
A.I.S.I. 309	<0.20	22-24	12-15	<2.0	<1.0	—	—	—	—	—	—	Bal.	—	27.0	18.0	7.8	4.3
A.I.S.I. 310	<0.25	24-26	19-22	<2.0	<1.0	—	—	—	—	—	—	Bal.	—	26.0	18.0	11.0	5.0
A.I.S.I. 330	<0.25	14-16	33-36	—	—	—	—	—	—	—	—	Bal.	—	21.0	12.0	7.5	4.0
Incoloy	0.10	20.5	32	1.0	0.6	—	—	—	—	—	—	Bal.	—	30.0	23.0	—	5.7
Table I, Group 2—Complex Chromium-Nickel Steels																	
GT-45	0.12	15.9	14.1	0.75	0.50	—	2.5	—	0.45	0.25	—	Bal.	—	43.0	37.0	16.5	12.0
16-25-6	0.10	16.0	25.0	1.35	0.70	—	6.0	—	—	—	—	Bal.	$0.15N_2$	45.0	34.0	13.5	9.0
19-9 DL	0.30	19.0	9.0	1.10	0.60	—	1.25	1.2	0.4	0.3	—	Bal.	—	52.0	38.0	17.0	10.0
N-155	0.15	21.0	20.0	1.5	0.5	20.0	3.0	2.5	1.0	—	—	Bal.	$0.15N_2$	50.0	40.0	12.0	8.0
EME	0.10	19.0	12.0	0.5	0.7	—	—	3.2	1.2	—	—	Bal.	$0.15N_2$	44.0	35.0	—	—
CSA	0.25	18.0	5.0	4.0	0.4	—	—	1.3	1.0	—	—	Bal.	—	50.0	39.0	—	—
HS-88	0.07	12.5	15.0	1.50	0.50	—	2.0	0.6	—	0.6	—	Bal.	0.025B	59.0	49.0	25.5	16.0
Refractaloy B	0.07	25.0	30.0	—	—	—	8.0	—	—	—	—	Bal.	—	—	—	—	—
Table II, Group 1—Early Nickel-Base Alloys																	
Nimonic 75	0.12	20	76	0.4	0.6	—	—	—	—	0.4	0.06	2.4	—	—	—	—	—
Inconel	0.04	15.5	76	0.35	0.2	—	—	—	—	—	—	7.0	—	22	14.5	5.7	3.7
Hastelloy B	0.10	1.0	65	0.8	0.7	—	28	—	—	—	—	5.0	—	54	36.5	16.2	10.0
Hastelloy C (cast)	0.10	16	57	0.8	0.7	—	17	4	—	—	—	5.0	—	49.5*	42.5*	19.0*	14.5*
60 Ni, 15 Cr	0.03	15.8	58.7	0.5	1.4	—	—	—	—	—	—	—	—	—	—	—	—
Table II, Group 2—Complex Nickel-Base Alloys																	
Inconel "X"	0.04	15	73	0.7	0.3	—	—	—	0.9	2.5	0.9	7.0	—	80	68	28	18
Inconel 700	0.10	15	Bal.	<2.0	<1.0	29	3	—	—	2.25	3.0	4.0	—	—	70	42	30
A-286	0.05	15	26	1.35	0.95	—	1.75	—	—	2.0	0.20	Bal.	0.3V	61	46	13.8	7.7
Nimonic 80	0.05	20	76	0.70	0.50	—	—	—	—	2.3	1.0	0.5	—	62.7	50.5	17.2	7.7
Nimonic 90	0.08	20	58	0.50	0.40	16.0	—	—	—	2.3	1.4	0.5	—	76.1	63.0	28.0	17.9
Incoloy 901	0.05	12.8	43	0.48	0.22	—	5.68	—	—	2.43	—	35	—	80.0	61.0	19.0	—
Waspaloy	0.05	19	58	0.70	0.40	14.0	3.0	—	—	2.5	1.2	2.0	—	—	—	31.0	20.0
M-252	0.10	19	54	1.0	0.70	10.0	10.0	—	—	2.5	0.75	2.0	—	—	—	29.0	18.0
Refractaloy 26	0.05	18	37	0.70	0.70	20.0	3.0	—	—	2.8	0.20	18	—	80.0	63.0	27.0	18.0
Nimonic 95	0.08	20	58	0.50	0.40	16.0	—	—	—	2.5	1.60	0.5	—	—	—	33.0	—
Table III—Cobalt-Base Alloys																	
S-590	0.40	20.0	20.0	1.5	0.7	20.0	4.0	4.0	4.0	—	—	24.0	—	48.0	38.0	20.0	16.0
S-816	0.38	20.0	20.0	1.5	0.7	43.0	4.0	4.0	4.0	—	—	3.0	—	66.0	50.0	26.0	18.0
HS-21 (cast)	0.25	27.0	3.0	0.6	0.6	62.0	5.0	—	—	—	—	1.0	—	51.0	44.0	22.0	14.2
HS-31 (cast)	0.40	25.0	10.0	0.6	0.6	55.0	—	8.0	—	—	—	1.0	—	56.0	45.0	28.4	23.4
HS-23 (cast)	0.40	24.0	2.0	0.3	0.6	66.0	—	6.0	—	—	—	1.0	—	58.0	47.0	27.2	21.8
V-36	0.31	25.0	20.0	0.9	0.5	42.0	4.0	2.0	2.2	—	—	Bal.	—	—	—	23.0	18.0


TOOL STEEL HANDBOOK
ALLEGHENY LUDLUM STEEL CORPORATION
PITTSBURGH, PA.

A prior background of experience in the metallurgy of nickel alloys for normal temperature service indicated that a nickel or nickel-copper matrix could be rendered age-hardenable by judicious additions of aluminum or titanium, singly or in combination, and this principle was extended to base compositions of nickel-chromium and nickel-chromium-iron. In the past 15 years, progress along these lines has been rapid; Inconel "X", one such alloy, was commercially introduced in 1939. Ultimately, the alloys listed as Group 2 in Table II, p. 120-B, were developed which, with refinement, exhibit strength characteristics (80, 60, 30, 20) that are a close approach to satisfying present requirements in jet and turbine applications.

The metallurgy of these alloys is so extremely complex that their development has been largely on an empirical basis. Their high strength does not depend upon hot-cold work, as in similar compositions higher in iron and listed in Table I, Group 2, but requires a series of carefully controlled thermal cycles that include solution treating and one or more aging treatments. The purpose of the latter is to precipitate a variety of intermetallic compounds in an appropriate dispersion that increases the creep resistance. Contrary to the usual concept of age hardening, these materials are generally used in the overaged condition, since it appears to be the physical presence of the precipitating phases rather than the lattice strains attending their formation that is of great benefit to the high-temperature strength. Some of these alloys contain columbium or tantalum, for scavenging or purposely added to form precipitates; molybdenum or cobalt is added primarily to strengthen the solid solution matrix.

The properties of these alloys depend to a critical degree upon processing history, especially treatment. However, when properly treated, these high-nickel alloys as a class are among the strongest available today. Some are serving in highly stressed applications at temperatures up to 1600 to 1700° F.

Cobalt-Containing Alloys

In the search for ultra-high-strength materials for jet engines, it was discovered that cobalt, either as the base material or as one of the major components, could provide a series of wrought alloys uniquely resistant to the weakening effects of elevated temperatures. The alloys shown in Table III contain chromium for scaling resistance, and some nickel and variable iron principally for strengthening and stabilizing the matrix. However, their excellent creep and rupture resistance depends largely upon a comparatively high carbon level together with such strong carbide-formers as columbium, tantalum, tungsten, titanium, and molybdenum. Compositions of this type generally do not require a precipitation hardening heat treatment; their high-temperature strength is due to dispersoids scattered throughout the stiff cobalt-containing matrix. Resistance to softening at high temperatures is presumably due to the stability of these refractory phases.

The alloys listed in Table III contain substantial concentrations of chromium and cobalt; some have sizable amounts of nickel and iron. They either have been or are now used in applications requiring strength as well as resistance to oxidation. It might be said that these are the newest varieties of heat treatable alloys; careful study of their chemical composition has resulted in systematic developments.

The number of other alloys that could be properly put into this group is large. Only those that are commercially available and also are known to have been adequately proven for such uses as jets and gas turbines are listed. Since choice of an alloy by its user does not always become known immediately, some alloys, preferred for some special reason, may have been inadvertently omitted from the table, in which case it should be considered as ignorance and not as a deliberate omission.*

Taken as a group, alloys of this class, with characteristic rupture strengths of 55, 45, 25, 20, show about the same strength at 1200° F. as the complex chromium-nickel-iron type alloys (Group 2, Table I), somewhat better strength at 1500° F., and pronouncedly better at 1600°.

High-Temperature Corrosion

The expression "heat resistance" has recently been expanded to include high-temperature corrosion resistance. Any intelligent selection of an alloy for high-temperature service cannot be based upon mechanical properties alone, but must accord at least equal importance to the alloy's resistance to deterioration in the particular environment where it is to be used. In fact this is the prime requirement which must be satisfied in numerous corrosive conditions; only then may a

*For a complete list of all alloys of this type, experimental or in various stages of development, see A.S.T.M. Special Publication No. 170, "Compilation of Chemical Compositions and Rupture Strengths of Super-Strength Alloys".

secondary selection be made on the basis of strength. For example, there is little doubt that pure molybdenum or molybdenum-base alloys would be most attractive materials, as pointed out by Roger Long in his article on p. 123 of this issue, if it were not for the fact that oxidation proceeds at a destructive rate at moderately elevated temperatures. Similarly, environments containing large concentrations of hydrogen sulphide require the use of high-chromium ferritic steels which, as a class, have considerably lower strength than obtainable in the austenitic compositions.

Laboratory investigations, as well as field corrosion tests in existing processes, have contributed a good deal to this little-known subject. Oxidation, possibly the most common form of attack, has received a large share of investigation. The physical and chemical characteristics of oxidation, the mode and rate of growth of scales formed on different types of alloys, have been intensively studied. This fundamental work is fortunately gaining in recognition and is carried on by several capable organizations. A better understanding of the process has led to the development of ceramic coatings to enhance the scaling resistance of those metals which may be deficient in this property, yet have sufficiently high creep strength to prevent cracking of the synthetic oxide film.

Other forms of attack, such as carburization, nitriding, halogenation and sulphidation, have received their share of attention more or less in proportion to their industrial importance. Increasing the silicon content increases resistance to carburization. In alloys having higher nickel contents, the same resistance is improved by increasing the chromium.

A relatively new form of high-temperature corrosion (and one which we could easily have done without!) is the attack resulting from the fly ash from certain residual fuel oils. When these oils contain appreciable quantities of vanadium, alkali metals, and sulphur compounds and the temperature of the metal surface is high enough for the ash to remain molten, an extremely severe type of attack occurs which apparently cannot be avoided by choosing a more resistant alloy since none seems to exist!

Corrosion by superheated water, fused salts and molten metals has been intensively investigated by various Atomic Energy Commission laboratories in connection with the use of systems for extracting heat in nuclear reactors. Workable solutions for this problem have been discovered.

Afterward

Thus, we come to the end of the resume of what has been happening in the field of high-temperature alloys during the past 25 years.

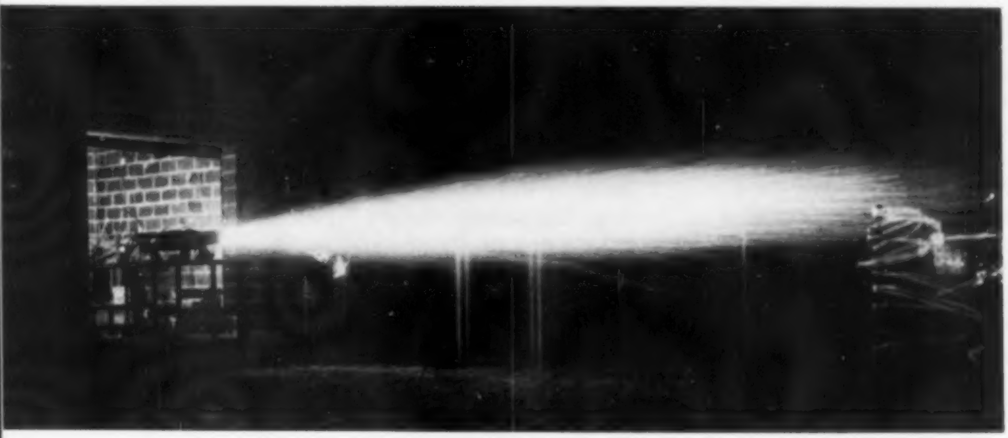
With a better understanding and control of variables, we could expect to develop alloys still stronger at temperatures now used, or alloys that maintain their strength as operating temperatures are increased. To be able to do this, we must engage in studies fundamental in scope.

In age hardening alloys (nickel-base), the nature of the precipitating phase is not yet established except in the most general form. In the presence of titanium (or titanium and aluminum) this phase is believed to be a complex compound of titanium (or titanium and aluminum) with nickel – or iron if the latter is present in considerable amounts. Carbides of columbium or titanium have been identified. Views concerning the effectiveness of different precipitants are still debated – indeed the actual effects are not always clearly known. Some workers in this field hold that carbon is definitely desired to achieve a specific kind and distribution of chromium carbides (along the grain boundaries), while others believe that a little carbon (on the order of 0.05 to 0.10%) is essential only for deoxidation.

The role of boron is much in debate. Trace elements are held responsible for some unexplainable behavior of nickel-base alloys, but careful and reliable data are not available, principally due to lack of precise means of detection and analysis. The effects of molybdenum, cobalt, tungsten, and vanadium on the strength and ductility of the matrix, on the solution temperatures and on the nature of precipitants are not established. Detrimental effects of cobalt and vanadium on oxidation resistance of the alloys are neither firmly established nor understood. The pronounced effects of heat treatment and its corollaries, namely, grain size, order-disorder structures and lattice imperfections have not been systematically and logically explored.

It is not our object, in listing these gaps in our knowledge, to belittle the studies now being carried out in many places. It is rather our firm belief that a frank acknowledgment of the voids in our understanding should be made plain and loud; that efforts, talents and facilities in some of our research centers should be shifted from the acquisition of unrelated data under all kinds of experimental procedures to the development of basic facts about which we are in the dark or in disagreement.

Exhaust End of a Ram-Jet During a Night Test



Super-Refractory Materials

*By ROGER A. LONG**

Most promising of the three varieties now known (there is no 25-year history in this new field) are the TiC plus metal binder (or vice versa), representing the cermets; $MoSi_2$, representing the intermetallics; and molybdenum, representing the refractory elements. (SG-h)

An article about "super-refractories" might well have been omitted from this anniversary issue of *Metal Progress*, reviewing progress in 25 years, because these materials were nonexistent in 1930. There was no industrial interest in them, even though some researchers may have been studying them in a quite limited way; furthermore, powder-metal fabrication methods had not yet been devised. Only with the rapid development of aircraft gas turbines and other power plants since World War II did the service temperatures of metallic parts rise to 1800° F. and higher – considerably above what could readily be withstood by the alloys known at the beginning of the quarter-century under review, and even today's so-called super-alloys.

This is the important field of super-refractories in 1955. It can be divided into three major categories – (*a*) ceramics and "cermets"; (*b*) intermetallics; (*c*) refractory elements and alloys. This article will describe briefly the developments in each field (as far as the information has been declassified and published), and will attempt to indicate the lines along which good chance for future progress may be expected.

Ceramics and Cermets

Ceramic oxides, because of their known resistance to oxidation at high temperatures and their low density, were among the first examined. In 1945 the National Bureau of Standards had perfected a high-strength refractory body, NBS 4811, of beryllium and aluminum oxides. It

*Manager, Aircraft Components Div., Ferrotherm Co., Cleveland; Consultant, Rand Development Corp.

had the highest rupture strength of any then-known fabricated material – approximately 17,000 psi. in 100 hr. at 1800° F. (After almost 10 years of study this is still one of the strongest of our materials.) On a strength-to-weight basis it is about four times as good as our best cobalt-nickel "super-alloy" at this temperature.

In 1947 the National Advisory Committee for Aeronautics evaluated NBS 4811 as a turbine blade in a simulated cyclic engine test and proved that refractory bodies could be used as turbine blades, even though in their existing condition they were too brittle and had poor resistance to thermal shock. The design and testing of these ceramic bodies, however, paved the way for the future of refractory materials and gave hope to the design engineer, ceramicist and metallurgist. "Super-refractories" may therefore be regarded as being about 10 years old.

While little data are available on pure oxide bodies, such as alumina and zirconia, it is known that they have high melting points, good oxidation resistance, low densities, and can be fabricated by slip casting, extruding or pressing. Their crippling disadvantages are poor thermal shock resistance and almost zero ductility.

Properties of Super-Refractory Materials

Designation	Evaluation Temp., °F.	Oxidation Resistance *(c)*	Maximum Mechanical Properties			
			Short-Time Ultimate	100-hr. Strength	Modulus of Rupture	Impact (80° F.)
		Oxides, Carbides and Cermets				
Alumina (Al_2O_3)	2200	Excellent	30,000	—	—	7 *(k)*
NBS 4811 c (48 BeO, 2 Al_2O_3, 2 ZrO_2)	1800	Excellent	18,500	17,000	—	—
70% Al_2O_3 plus 30% Cr	2000	Excellent to 2200° F.	18,500	14,000 *(f)*	33,000	—
Cr_3C_2	1800	2.0 in 100 hr.	—	18,000	90,000 *(a)*	—
K 175 B (TiC plus 60% Ni-Mo-Al alloy)	1800	Growth: 0.0026 in. in 180 hr.	100,000 *(d)*	16,000	—	—
K 162 B (TiC plus 30% Ni-Mo alloy)	1800	Growth: 0:0023 in. in 180 hr.	115,000 *(d)*	13,000	25,000 *(a)*	6.3 *(h)* 3.2 *(i, l)*
TiC (infiltrated)	1800	—	—	16,000	150,000 *(b)*	10.0 *(j)*
FS 26 (54 TiC; 40 Ni; Cr_3C_2)	1800	47.6 in 200 hr.	41,000	11,100	—	4.5 *(i, l)*
OSU-3 B (73 TiC, TiB_2, plus 27% CoSi)	1800	2.0 in 100 hr.	30,000	27,000 *(f)*	—	—
Metamic LT-1 (72 Cr plus 28 Al_2O_3)	1800	Excellent	16,000	4,000 *(f)*	—	11 *(k)*
50% MgO, 30 TiN, 20 NiO	80	—	—	—	47,000 *(a)*	—
B_4C plus 13% Fe	1800	—	—	—	31,000 *(a)*	—
		Intermetallics				
Borolite 101 (ZrB plus B)	1800	15 in 200 hr. at 2000°	40,000	18,500	63,000 *(a)*	—
Borolite 402 (CrB plus metal)	1800	10.6 in 100 hr. at 2000°	—	14,000 *(g)*	150,000 *(b)*	—
50% Cr_3Si plus 50 Cr	1800	Excellent	—	—	130,000 *(b)*	—
Chromium titanide (Cr_2Ti)	1800	8 in 200 hr.	—	—	87,400 *(b)*	—
Cr_2Ti plus 5% CrO_2	1800	8 in 200 hr.	—	±15,000	111,200 *(b)*	—
Nickel aluminide (NiAl)	1800	2.0 in 200 hr. at 2000°	—	12,000	70,000 *(b)*	15 *(h)*
Molybdenum disilicide	1800	3.0 in 135 hr. at 2850°	42,000 *(e)*	> 30,000	90,000 *(a)*	—
$MoSi_2$ plus 6% Co	1800	2.0 in 100 hr. at 2000°	—	—	76,100 *(a)*	—
Titanium disilicide ($TiSi_2$)	1800	2.0 in 200 hr.	22,000	—	30,000 *(a)*	—
		Refractory Elements and Alloys				
CM 469 (60 Cr, 25 Mo, 14 Fe) (as swaged)	1600	Excellent	—	37,800	—	—
Molybdenum (as swaged)	1800	None	33,000	19,300	—	—
Molybdenum plus 0.5% Ti	1800	None	—	53,000	—	—
(stress-relieved)	2000		—	34,000	—	—
Molybdenum plus 0.05% Zr	1800	None	—	> 60,000	—	—
(stress-relieved)	2000		—	40,000	—	—

(a) 2-in. span. *(b)* $\frac{5}{8}$-in. span. *(c)* Loss in mg. per sq. cm. of surface *(d)* At 80° F. *(e)* Up to 2400° F.
(f) In 1000 hr. *(g)* In 3000 hr. *(h)* Impact (in-lb.) N.A.C.A. drop test. *(i)* (in-lb.) unnotched Charpy.
(j) (ft-lb.)—unnotched Izod. *(k)* (ft-lb.) A.S.T.M. ceramic Charpy. *(l)* (ft-lb.) unnotched Charpy.

The alternative is to add to the ceramic powder a metallic element or alloy of high conductivity and ductility, in the hope that the thermal shock and the impact resistance would be increased into a useful product. These have been called "cermets." One of the first consisted of 70% alumina and 30% chromium; it was first studied at Ohio State University, and again this early mixture is about as strong as any cermet later formulated (see the table on p. 124). It has good oxidation resistance, but like the ceramic oxide bodies, lacks thermal shock and impact resistance. Even so it will probably be good enough for use in the less exacting situations.

Another interesting approach, utilizing the same materials, was to reverse this composition, utilizing approximately 72% Cr and 28% Al_2O_3. Maybe this should be referred to as a refractory alloy rather than a cermet. Resistance to thermal shock properties is considerably improved, but brittleness and strength are not.

Many other true cermets have been and are being investigated. Oxides include alumina, chrome, magnesia, silica, zirconia and beryllia. Metal additions, singularly or in combination, have been aluminum, cobalt, nickel, chromium, iron, zirconium, beryllium, manganese and molybdenum. No large benefits have been achieved from these combinations to date.

Carbide Cermets

Metal carbides are included in this classification of cermets, primarily because carbides of the transition metals have to be alloyed in order to receive consideration. The one with the most promise to date, titanium carbide, has poor oxidation resistance above 1650° F., and its short-time tensile strength at 1800° F. is only about 15,000 psi. However, when alloyed with nickel, chromium, molybdenum or cobalt, even where the binder metal becomes the base alloy, tremendous advantages are gained. Resistance to oxidation increases and tensile strengths up to 40,000 psi. at 1800° F. are exceeded, together with considerable improvement in thermal shock and impact resistance.

These carbide cermets are best exemplified by Kennametal's series K 138 A through K 175 B and Firth-Sterling's FS-2 through FS-27 series. Their properties are shown in the table. When based on strength-weight comparisons to the nickel-cobalt superalloys, the rupture strengths are about double. Thermal shock resistance is generally greater than any other ceramic, cermet or intermetallic yet formulated. Resistance to fragmentation or impact at room temperature is as high as 3 to 4.5 in-lb. by unnotched Charpy tests. Impact resistance generally remains about constant with increasing temperature or decreases slightly. Some data on notch effects have shown similarity to ductile metals.

These alloys have best exemplified the work of the metallurgist. Utilizing a base compound which had only fair resistance to oxidation, by constant development he has improved the strength, oxidation resistance, impact and thermal shock resistance of the body. For example, if we compare the recent K 175 B with the original Kennametal K 138 of about 1950, oxidation resistance is 7 to 10 times greater.

Titanium carbide cermets have been extensively investigated for attaching turbine blades to rotors. Results have been excellent, although reliability (scatter of results) leaves something to be desired. The present author believes they may be used in the intermediate range of operation (1600 to 1800° F.). Harmful effects of surface discontinuities may be minimized by a diffused coating such as chromizing, aluminizing or nickel impregnating.

Thermal shock and toughness are improved by "infiltering" a skeleton of titanium carbide with high-nickel alloys. The original form of controlled porosity is made by powder metallurgical methods, and the entire process lends itself readily to the production of complicated shapes. Space permits no more than mention of some other recently studied possibilities listed in the table on p. 124, such as chromium carbide (unalloyed), boron carbide with iron binder, and silicon carbide (long used as "Glo-Bar" resistors in electric furnaces).

Intermetallics

The next category is in a relatively new field of metallurgical development. It will be designated here as "intermetallics," although other names are "metal compounds" and "hard metals". It includes the borides, hydrides, nitrides and silicides of the transition metal elements of the fourth to sixth group in the periodic sequence, combined with semimetallic elements of small atomic diameter. (By rigorous definition, the carbides should have been included, but it is more convenient because of past usage to put them into the category already described.) A number of these materials have shown excellent high-temperature properties in an unalloyed condition, and their metallic nature gives them a considerable advantage over the ceramic ma-

Cermet Wheel Being Cut by Electric Spark Method. (Courtesy of Firth Sterling, Inc.)

terials as to thermal shock and brittleness. They are also of low density when compared to the superalloys based on nickel and cobalt.

The borides, whether the metal is titanium, zirconium, molybdenum or chromium, have poor oxidation resistance above 1800° F. Their 100-hr. rupture strengths at 1800° F. resemble the cermets, ranging from 10,000 to 16,000 psi. Their high melting points (mostly above 4000° F.) fit them for very high-temperature, short-time conditions – for example, rocket nozzles where strength is not a major factor.

The hydrides are not stable at elevated temperatures, but may be valuable as additions to other refractory bodies.

The nitrides are also a relatively unknown group of materials and therefore unlisted in the table. Chromium nitride, titanium nitride and silicon nitride are of interest primarily because of their low densities (2 to 5.7) and their very high melting points. Titanium nitride has a melting point of 6000° F., and when hot pressed and sintered at 3900° F. to a density of 5.2, it has a modulus of rupture of 26,000 psi. at 80° F. and 20,000 psi. at 1800° F. Its oxidation resistance is only fair. While the nitrides may have more advantages than now indicated, their main possibilities seem to be as addition compounds to other intermetallics. For example, a promising recent material contains 50% magnesium oxide, 30% titanium nitride and 20% nickel oxide; this has a modulus of rupture of 47,000 psi. at 80° F.

Molybdenum Disilicide

Silicides of the transition metals are probably the most important intermetallic compounds studied to date. Molybdenum disilicide ($MoSi_2$) has shown the best properties for high-temperature applications; titanium and chromium silicides also have possibilities.

Molybdenum disilicide has excellent oxidation resistance up to 3000° F.; its 100-hr. rupture strength at 1800° F. is over 30,000 psi. (about twice that of the best cermet tested to date). Loaded at 10,000 psi. and held 50 hr. at 2000° F., it elongates about 10%; creep is therefore a design limitation. Its thermal shock resistance is deficient in the present stage of development.

Molybdenum disilicide has been alloyed with nickel, cobalt and platinum to improve its impact strength. Cobalt seems to be best, but there was little improvement in thermal shock characteristics. The mechanism of the "alloying" action is not known; however, there is a strong tendency to form tertiary silicide compounds or eutectics. Recent modifications, in which small percentages of an oxide were added, decreased the creep rate at 2000° F. Another interesting field for future study is the use of $MoSi_2$ as a binder for oxide and carbide bodies.*

Titanium disilicide, with the low density of 4.2, is also of interest; however, its oxidation resistance and lower strength limit it to possible uses at less than 2000° F. It has appreciable ductility at temperatures above 1800° F.

The main disadvantages of the silicides seem to be their poor resistance to thermal and to impact shock; however, this difficulty is believed to be curable by improved powder manufactur-

*EDITOR'S NOTE—Fabrication and properties of $MoSi_2$ were studied extensively by Mr. Long at Lewis Flight Propulsion Laboratory of N.A.C.A. between 1947 and 1950. Patents and reports were issued.

ing methods prior to fabrication into a part.

Other intermetallics which are being considered as possible high-temperature materials are the nickel aluminides and the nickel, chromium and nickel-chromium titanides. These have been investigated primarily because of their low densities and because the preliminary oxidation tests were satisfactory.

Nickel aluminide has excellent resistance to oxidation and thermal shock. The impact strength is about triple that which has been obtained with the carbide cermets.

The titanides are a new type which utilizes titanium as a semi-metal because of its small atomic diameter, low density and its ability to form intermetallics. The strengths that have been obtained at this early stage of development fall within the general range of other cermets and intermetallics. Chromium titanide with a 5% CrO_3 addition has shown a 100-hr. rupture strength at 1800° F. of about 15,000 psi. Thermal shock and impact strength have not been determined nor published as yet. Oxidation resistance seems to be somewhat less than for aluminides and disilicides.

Refractory Elements and Alloys

This third category has exceeded the other two in its developmental status. The principal elements that have been examined are chromium, molybdenum and titanium. Chromium has been studied rather closely by men in the U.S. Army Arsenal Laboratories and an account of these activities is planned for the A.S.M. annual convention in Philadelphia next month. Molybdenum has been studied by a commercial firm, Climax Molybdenum Co., and the results summarized in the current series of articles in *Metal Progress* by N. L. Deuble. Tremendous sums of money have been poured into molybdenum and titanium by the military agencies.

Unalloyed chromium has been eliminated from consideration because of brittleness except in small or thin test pieces. There is a chance, of course, that someone may discover the cause of this, and make more massive parts with an acceptable degree of toughness. The high-chromium alloys have not fulfilled anticipations, as far as the present writer is able to state. However, data published a few years ago about a vacuum-cast alloy designated as CM 469, containing 60% chromium, 25% molybdenum and 14% iron, showed a 100-hr. rupture strength at 1600° F. of over 37,000 psi. This alloy also was very brittle, but recent developments in vacuum melting and heat treating techniques have tended to correct this situation.

Titanium or high-titanium alloys have shown no promise for use in the temperature range we are considering.

It is well, then, that the refractory element molybdenum has many attractive properties, such as availability, ready fabrication by conventional means, and strength at elevated temperatures. The arts of alloying, arc casting, extrusion, rolling, and stamping have been perfected and brought its practical use much nearer. The pure metal's strength at 1800 and 2000° F. is higher than the superalloys and cermets available today. Its 100-hr. rupture strength at 1800° F. is about 19,000 psi. Minute additions of alloying elements, such as titanium and zirconium, have a tremendous influence on high-temperature strength properties and the recrystallization temperature. For example, 0.5% Ti brings the 100-hr. stress-rupture life at 1800° F. up to 53,000 psi., which is about three times that of the pure metal. The table on p. 124 shows that the alloying addition of 0.05% Zr is even more potent.

Let us compare these strengths with all the cermets and intermetallics. Generally, the 100-hr. rupture strengths of cermets and intermetallics, excluding molybdenum disilicide, fall within the range of 10,000 to 17,000 psi. at 1800° F. Therefore, alloyed molybdenum is three to five times stronger! Its strength is almost double that of molybdenum disilicide, the best of the competitors. There is one fly in this ointment: If compared on a strength-to-weight basis, molybdenum has far less advantage since it has a high density (10.2).

The two properties that may eliminate molybdenum from wide use at present are its poor oxidation resistance and its brittleness. Brittleness at room temperature seems to be related to a number of fabrication variables which affect the transition temperature and doubtless can be alleviated as knowledge increases. The major problem, *rapid* oxidation, awaits the discovery of some coating process. Considerable work has been done on this within the last few years. Tests of numerous coatings have shown that they protect the base metal if they are continuous. Such include fused coatings, chromium plating by new techniques, and the use of double or triple coatings. One of the major problems has been the inconsistency of results. Oxidation proceeding from one microscopic pinhole will destroy the hot molybdenum part in a matter of seconds at any of the temperatures contemplated. Any

damaging impact, such as happens if a grain of sand gets sucked in with air for the turbine in service, will puncture the coating and the blade will go almost immediately.*

Possibilities for Progress

As remarked at the outset, the Editor's request that contributors review a quarter of a century's progress, state some of the most prominent features of today's landscape and point out some avenues of advance, can hardly be complied with in the field of super-refractories. The subject matter is so new that the most of this article has been given to a review of the *present* situation. It would appear to the present author that titanium carbide plus metal binder (or vice versa) is the best of the cermets now known (or divulged), that molybdenum disilicide is the best of the intermetallics, and that molybdenum is outstanding among the refractory elements.

Each has serious deficiencies accompanying their striking excellences.

Where do we go from here?

Strangely enough there is today, even after 10 years of development, no gas turbine engine in production which utilizes the refractories we have described! There is no question but that their use would be much further advanced if investigations into *design* were equivalent to the investigations into the *materials*. A material of construction cannot truly exist without a design; a design cannot be built without a material. Each is a driving impulse for the other.

The first avenue for advance is, then, adequate study of the design problems involved in the use of unconventional materials.

As to the materials, future students of cermets must certainly first examine the effect of the "addition metal" (or alloy) on the base refractory compound, and the metallurgical mechanism operating upon the various mechanical and physical properties of the finished body. I would quote Prof. John T. Norton of Massachusetts Institute of Technology to the effect that cermets would be much further advanced if we had examined the theoretical concepts of aggregates and the basic relationships of binder to refractory compound. He suggested studies on representative aggregates which might have no connection whatever with high temperatures, but in which the variables could be closely controlled. Such results would be basically important.

*Editor's Guess–A fuel additive which would maintain and rebuild a protective layer may be the eventual answer.

The second avenue for advance is, then, fundamental studies on the physical interactions between compounds and metals.

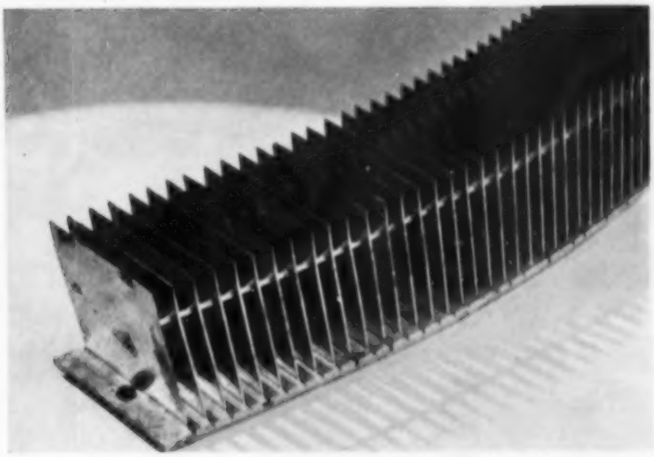
Especially in the field of intermetallics, it seems that too much work has been done on the properties of some particular compound without making sure that this particular compound prior to evaluation is in the best form possible. That the techniques used during the synthesis of a particular powder compound can make a considerable difference in the mechanical and physical properties of the resulting body has been clearly shown by work on titanium carbide and molybdenum disilicide. Any research program should, therefore, determine first whether the metal compound has any value for use at elevated temperatures by fairly simple tests (such as modulus of rupture, oxidation resistance, and crude thermal shock) to screen the hopeful from the hopeless materials. The next step would be to work with the best of the compounds in powder form, disregarding all other factors than how to make and fabricate it into cohesive bodies. Once this has been done, an extensive program can then investigate its oxidation behavior, thermal shock, impact resistance, stress-to-rupture, creep, and alloying behavior.

A third avenue for advance is, then, research into the manufacturing variables which must be eliminated before the refractory compounds can be put into optimum condition.

Much money can be spent on intermetallics with little result. For example, the probability of obtaining a new material or a new compound that will exceed the best intermetallic now known, molybdenum disilicide, is questionable. The money should better be spent on the present materials – such as, for example, a search for the reason for the excellent oxidation resistance of the disilicides as compared to the other silicides of the same transition metals. Protection is apparently afforded by the formation of silica (and cristobalite) on the surface. However, an analysis of the other silicides of the same transition metals shows the same silica-type layer, but this layer does not protect! The atomic architecture (the location of the metallic atom with reference to the semimetallic atom) may be responsible. If the mechanism for this particular action in this group of materials could be understood, the same analogy might be used with other materials, and oxidation resistance improved.

A fourth avenue for advance is, then, research into the fundamental mechanism which provides

(Continued on p. 190)



Typical of the Assemblies Silver Brazed in Furnace Containing Protective Gas

Welding and Joining

*By A. B. KINZEL**

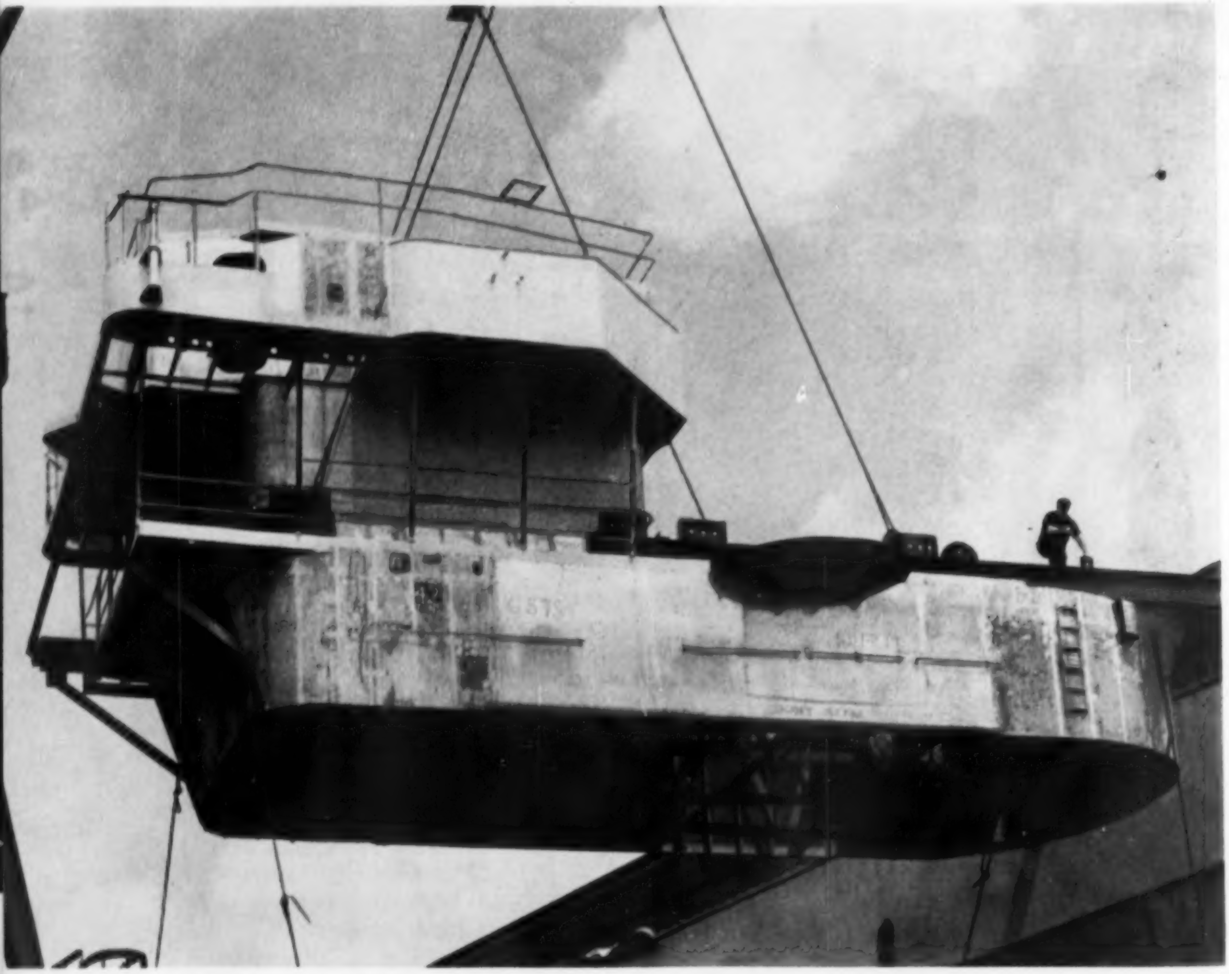
The specialty welding of 25 years ago has become routine; the submerged arc and inert-gas shielding have sparked a minor revolution in the industry; and new design concepts have resulted from welding research. (K general)

ANNIVERSARIES are the occasion for taking stock and attempting to peer into the future. Any such attempt is in essence an extrapolation of the past, and so a look at the last 25 years is in order.

It is not easy to recreate the atmosphere of the late twenties – the days of boom and bust. When we do, a startling fact is that in welding there was no bust; it was all boom, perhaps not forceful but boom nevertheless. The technology of welding and its industrial application were advancing at a rapid rate; an even greater reason for the boom was the effect of basic research on the rate of increase in understanding. At that time gas welding dominated the field. Pure iron was the favorite metal for deposition but welding rods containing alloying ingredients had just been introduced and the quality of weld metal was markedly improved. Electric welding was restricted to bare electrodes and the concomitant nitrogen and oxygen pick-up was more than deleterious to quality. But the research laboratories were full of new ideas: Protect the weld metal; shield the arc; deoxidize the deposited material; coat the electrode.

These concepts were just coming into the industrial picture. They truly revolutionized the industry and opened an ever-growing vista of

*Vice-President, Research, Union Carbide and Carbon Corp., New York.



Welding Beat the Submarine. Completely welded forward deck house being hoisted to its position on a destroyer's hull—60 ft. long, 30 ft. wide, 30 ft. high, weighing 42 tons. (Courtesy Federal Shipbuilding & Dry Dock Co.)

potentialities. Submerged-arc welding – then only the germ of an idea – came a bit later and provided impetus to the mass-production methods responsible for the tremendous growth of the industry. Some 10 to 15 years after the boom and bust days we were in World War II and the manufacturing techniques which provided armament at undreamed-of rates were based largely on those welding processes.

The welding of a "specialty" became less a research project and more an industrial operation. It was no longer "special". I refer specifically to such things as the solid-phase welding of railroad rails, oil well drill pipes and high-strength steels, and the welding of high-pressure power piping and stainless steels. Resistance welding and "shot" welding, with a speed approaching infinity, found a place in this development where the rate and amount of mass production justified the capital investment.

Another welding revolution has taken place since World War II – in fact, we are now in the middle of it. Instead of solid and liquid materials such as oxides and silicates to protect arcs and arc welds, inert gases are being used. These processes require very large quantities of inert gas. Helium has been readily available in America, but argon has changed from a true rarity to a major industrial product available in practically unlimited quantities. Protection by inert gas

changed the scientific and technological problems radically and established a new point of view for the research and welding engineer. The changes taking place in a protected puddle of molten metal are reduced to a minimum. Slag removal and chipping are eliminated. Visibility is restored. Inert-gas welding bids fair to become a major method and will have an important impact on other processes. In all probability, however, it will increase the use of welding to such an extent that, on net balance, there will be no important decrease in the use of the conventional processes.

Flame Cutting

Although this paper is on joining, a word on flame cutting is in order. Precision has increased tremendously. Thickness of material that can be cut readily and to better advantage is ever increasing. By introducing metal powder into the oxygen stream, cast iron and stainless steel can be cut. Nonferrous metals are also being cut in this way, and cutting techniques have advanced almost in the same measure as joining. Moreover, steelmaking itself has been affected in major degree by scarfing and skinning processes.

New Concepts of Design

The enormous increase in welding could not have come about without a parallel development in concepts of design. Riveted construction was based on slippage rather than plasticity, or perhaps we should say in welded construction it was necessary to provide plasticity in lieu of the slippage. Moreover, welding made butt joints possible – riveting is restricted to laps. It is to the credit of the welding industry that it had sufficient vision to support research in design.

Thus it happened that the welding industry was in the forefront in the development of welded pressure vessels, containers of all types, and even ships. The elliptical head with two-to-one ratio for pressure vessels is one of the first instances in point. Another example in the same field is the use of welding to reinforce any opening so that high local stresses are eliminated. The thin-web girder for structures and – what bids fair to be a major development of the future – the wedge-beam are both the result of research either carried out directly or supported by the welding industry.

In shipbuilding, the problem has been long and difficult. To get the ships necessary in World War II welding was obviously essential. They simply could not have been built in quantity in any other way. It is not strange that certain difficulties arose; the wonder is that there were so few. This, in spite of the tremendous amount of publicity given to the small percentage of welded ships which cracked in one way or another. Major investigations were undertaken by many groups and it became apparent that three factors were involved; also that when any one of these factors was in order the vessel remained sound even though the other two were adverse. The three factors were *workmanship* (the quality of the deposited weld metal), the *base material* of construction (the type of steel from which the vessel was built), and *design*.

Obviously, in a speeded up war-production program the workmanship was not of the best. This is something we had to live with; human nature being what it is, it is probable that this factor will rear its ugly head from time to time in the future.

As the base material, semi-killed steel was used almost universally. Though it is less ductile under many conditions than killed steel, the production program could never have been completed with killed steel. There simply was not enough of it.

As to design, welding engineers have talked about the danger of notches for more than 30 years. So have metallurgists, but the importance of this major factor has not fully penetrated the designing engineering profession even yet. It is amazing, and to many of us incredible, how often a beautifully finished job will be seriously damaged by the stamping of letters or numbers into otherwise uniformly stressed steel. Notches certainly played their role in ship design. A sudden transition from a superstructure strake to the hull proper was fairly common, and this is a really bad notch. Square hatch corners were the rule – an even worse notch. Of the various investigations of the fracture problem in its broad aspects, it may be truly stated that those studies which brought out the importance of all three of these factors in their proper relationship were supported by the welding industry or carried out by scientists or engineers in the welding field.

Welding allowed major advantages in design but we could only take advantage of these as a result of research and study. Again, the great variety of steels used in structural engineering meant that a steel's weldability be correlated with its other properties. This the welding industry undertook, and the information on optimum design and type of material is now available and is being generally used by the engineering profession. In fact, the welding industry has provided

a handbook on the weldability of steel which has proved to be a boon not only to the designing engineer but to the metallurgist as well.

Interrelationships

So much for the past. Before considering the future, let us ask the question, "How much of that which has just been related could have been predicted 25 years ago?" I am afraid that very few of the eminent welding engineers of that day could have even hoped for, much less predicted, what has come about.

Economists tell us that there is a typical curve for most industries which starts up rather slowly, becomes increasingly steeper and then as time goes on becomes less steep and finally flattens out – always provided that technical obsolescence does not result in a downward slope and an approach to zero. The welding industry is currently on a steeply rising slope and there is no indication that we are even approaching the time when the rate of increase will diminish. The industry is young and vigorous. Certainly we may expect marked development in those processes already known.

Welding, like so many other industries, draws on all the sciences. Simple chemistry and fluid mechanics were the basis for the original processes. Metallurgy advanced the art and science of welding tremendously. Applied mechanical sciences furnished much. Physics is today playing an important part and one that bids fair to become even greater in the future. As the wavefront of knowledge goes forward, new phenomena appear and the alert, imaginative scientists in the welding area will certainly seize on these to dream up new processes for the welding engineer to develop. This inventive and development process is self-generating and self-stimulating so that we can look forward to a greatly expanded welding industry 25 years from now. Costs will be lowered and quality increased; new processes will bear little resemblance to those we now know or even visualize.

A Hypothetical Process for 1980

In conclusion, one cannot resist the temptation to emulate Jules Verne. With the hope that the following disclosure – now unworkable – will in nowise prejudice the patent position of some future brilliant scientist, I will describe one of the welding processes that might be in use 25 years hence.

An oxygen cut is produced by making a chalk mark with solid acetylene along the line to be cut. The article has been placed in an oxygen-filled chamber with an electric potential across the cut so that, once started, the cut follows the line of the acetylene chalk mark but goes vertically through the plate. The cut surface will then be sprayed with an isotope that will decompose atomically to the same metal as is being welded. The assembly will then be submitted to neutron bombardment and the isotope decomposed. (The word decomposition is here used in its true sense, namely, change in the nucleus.) It should be remembered that this will generate heat, but by controlling the concentration and length of time of neutron bombardment, only a few atoms will be generating heat at any given split second. Further, at this stage, the atoms will be in a high state of excitation and will in effect be the atomic equivalent of the chemically nascent state. Thus we will get high "atomobility" and ready breakthrough of boundary layers of adjacent crystals – which is another way of saying crystal growth across the interface. At the same time, if the sprayed material carries a predetermined modicum of hydrogen-containing atoms, these too will be excited; the nascent hydrogen thus produced will truly be atomic hydrogen and will automatically reduce any oxides or other reducible foreign material left from the preparation step. The heat generated will be great but so localized that while we have a molecular "liquid" phase, in essence it will be a solid-phase operation and the gross heat will be so localized and so rapidly withdrawn by the base metal that again, in essence, we have cold welding – there is no "heat treatment effect" whatsoever on the base metal. Moreover, the total heat involved will be so small (because of the extreme thinness of the sprayed isotope layer) that thermal stresses will cease to be a problem, stress-relieving will be unnecessary, and we will be in a perfect position to weld the space ships in such a way that they can travel to the moon with no secondary structural difficulties.

I am sure that anyone skilled in the nucleonic art will appreciate the simplicity and effectiveness of this procedure. I am equally sure that such a person could offer as many objections with positive proof that this cannot be done as any good scientist could have thrown at Jules Verne in the days of his "20,000 Leagues Under the Sea". But today the Nautilus *can* do 20,000 leagues under the sea, and in one of the tomorrows a welding operation broadly corresponding to the foregoing may well be possible.

What the Future Holds for the Foundry Industry

By GEORGE W. CANNON*

Progress in the foundry industry will be most stimulated by sound, scientific management and by the establishment of good apprentice training programs. (E general)

When I was asked to write about the future of the foundry industry for this Anniversary Issue, I wished at first that I had been asked to talk about the past 50 years rather than the years ahead. But now I am glad because I have had to go to the old plants and men I knew so well and ask each one: "What's new? What can I tell my friends about your operations and plans for the future?"

I have traveled around to see the plants of Ford, Chrysler, Buick, Chevrolet, Saginaw Malleable, International Harvester, Crane Co., Auto Specialties, and several smaller plants. I have visited with the executives to talk foundry problems, research, and new developments. You would be as interested in what I saw as I was.

As one top foundry head put it, "There are more new and interesting things in the foundry now than at any time since I entered it 30 years ago." And a prominent research man said, along the same line, "There will be more interesting foundry developments in the next five years than we have seen for the past 50."

Where were we 50 years ago? The automobile industry was a baby—just starting to walk. The machine age was at hand but the electrical age had hardly begun. The agricultural and plumbing industries had started quality production in their foundries. They had a few hand-stripped and roll-over machines and crude roller conveyers but there mechanization ended.

This was the beginning of our 20th century industry. Lights were mostly oil torches, for few had gas or electricity. Buildings had dirt floors and primitive toilets. Smoke and dust were endured, not controlled. Cupola metal and salamanders provided the only heat. Cupolas were all hand charged; iron, coke and stone were raised by cable inclines. A few shops had electric cranes for handling big castings. Labor in those days was 14¢ an hour and the journeyman molder got 30¢.

Metallurgy consisted of fracturing test blocks poured at the spout and eye estimation of carbon and silicon. Pig iron was used but sparingly, and we seldom melted steel in the cupola except for the semi-steel mixtures. Manganese and ferrosilicon were our only alloys.

As the automobile industry grew, so did foundries. World War I brought on new problems and new foundry growth. A few foundries started to specialize. Up in Muskegon, I recall, our company decided to turn from a jobbing business to making just five types of automobile castings. We thus directed our talents to obtain consistent quality at lower cost. We had piece rates so that the 30¢ per hr. operator might earn 45 or even 60¢. The owners did not take out much more.

Production foundries have come a long way

*Co-Founder of Campbell, Wyant & Cannon Foundry Co., Muskegon, Mich.

since then. Many a small and progressive job shop has also kept pace. Still you all have seen foundries in 1955 that are as dirty and as crude as if they were a part of the 1918 era.

Foreign Foundries

In the past several years I have visited nearly 100 foundries in nine European and South American countries. I have seen highly efficient plants with 3000 employees and I have been in small shops with little mechanization and no better facilities than American shops had 30 years ago.

For technical engineering and metallurgy, the best of the foreign foundries hold their own with us. They lack the quality of the melting materials available to us, but control is excellent and the castings high in quality. In some the production output is remarkable and, mind you, this is on wages equivalent to 40¢ to 70¢ an hr. in American money.

Some European plants have been ahead of us in cupola practice and design. We call nodular iron *new*, but it was made over there in the 1920's, I am told. Alloyed irons are their specialty and they often have a metal specifically developed for each application.

Shell molding got its real impetus in Germany in World War II. Today we may have better resin sands but as to that I am not too sure. We are ahead of them in engineering our systems of sand preparation, reclamation and handling. We have done a much better job than they in our newer plants on dust control. They have us beat in training manpower. Their apprentice courses are worth our study. In fact, we may be still drawing our future foundrymen from the European countries if we do not train more craftsmen in American shops. For that reason, apprenticeship training simply cannot become a forgotten part of our industry. It is not an added expense; it is the wisest investment a foundry can make.

Foundry Plants of the Future

Now let's look ahead for the U.S.A. We can start with the plants. One leading engineer said to me recently, "The building is only a suit of clothes that covers the layout and equipment." Still he is already dissatisfied with a big plant completed less than three years ago. He speaks of the foundries of the future as being as advanced in cleanliness, in their filtered air, in temperature controls, and in lighting, as any other modern industrial plant. It's up to management to carry the ideas of good housekeeping and safety out into the shop. It will start a favorable train of events. Cleanliness means good working conditions, a safer place to work, better labor relations, and a high-quality product turned out efficiently. A good measure of success would be this question: "Are you slightly ashamed of the condition of your shop when showing it to a visitor?"

Layout and facilities will be selected and installed in the future foundries with special attention to control of gas, smoke, heat, and dust *at the source*. There will be no spillage of sand or molten metal. Temperature will be controlled by circulation of fresh, clean, and cool air. Dirty and noisy departmental operations will be isolated. We must strive for all possible reduction of physical effort in the medium and heavy jobs so that women, if necessary, could do the work.

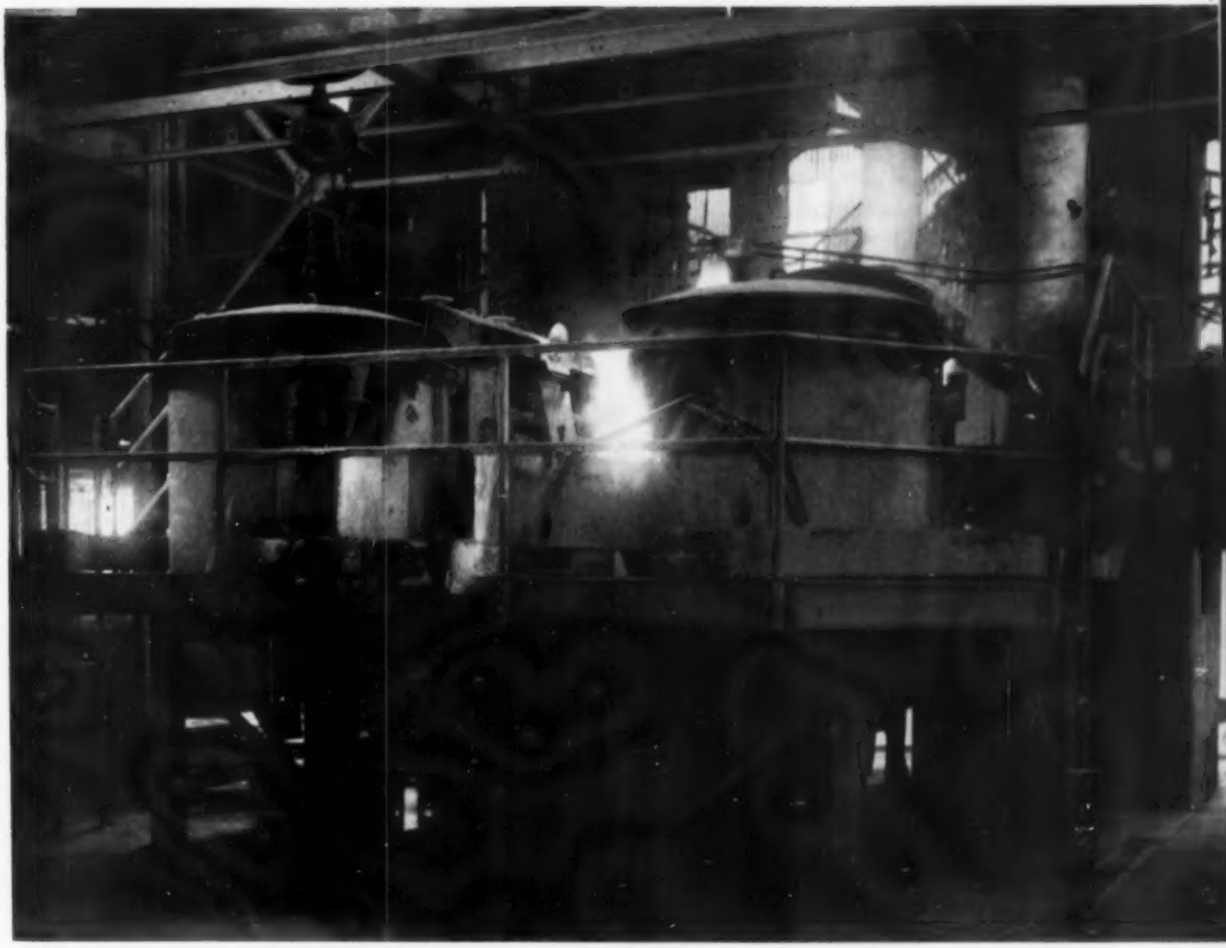
Automation is a new and popular word today. First, we had mechanization and then we had automatic machines. Today the engineer links several automatic machines together mechanically or electronically and calls it automation. We are still quite a way from having a completely automatic foundry or molding department, but we have already been applying the elements of automation to the foundry business for many years.

More, much more, of this is ahead. We must find ways to make work better, faster and at lower cost. All machines must be engineered and selected for minimum downtime and low maintenance cost, for the assembly can be no better than its slowest machine; when one machine is down, the whole unit stops.

Four Types of Foundries

Doubtless the trend toward specialty shops will continue in the future, since a foundry must specialize to compete with low-cost captive plants or to be a supplier to high-production industries. But there will always be a necessity for the local jobbing plant to supply the scores of small-quantity buyers in every sizable community. In fact, a logical classification might place foundries in four groups:

1. The jobbing shop, operating with a minimum of control, producing floor, pit, bench and machine jobs. Job shops may work without conveyers and with no central sand system. If the manager is not careful he can be talked into making too wide a range of work, or too many kinds of iron for his own good or for the good of his customers. Job shops can all benefit by



Cupolas With Forehearths Melting Iron for Shell Molded Castings at Lynchburg Foundry Co.

outside help of specialists in engineering, management control, and laboratory service.

2. The semi-production foundry. By intelligent selection of work and with some well-engineered mechanization, these plants can handle medium-sized production runs, and also specialize in certain classes of work. They can compete for work outside their local areas. They should strive for adaptability to handle light to medium weight jobs. They need engineering control and must do some research if they are to grow. In addition, they must advertise and must do a selective job of selling.

3. The high-production plant, independently owned, competes with the captive foundries for steady running jobs. These plants must have the latest in plant engineering and layout, fast, modern equipment, metallurgical control of quality, a sound accounting system, and good cost control. This category includes specialty plants which limit the business to definite classes of work or to castings that fit into a very limited number of flask sizes. In order to grow in a healthy fashion, these plants should have a progressive research department not only to expand the fields of usefulness of castings but also to develop some improved specialties.

4. The super-production plant constitutes the fourth type. The tendency today is for these to become captive plants. The costs of automation and high-speed mechanization are enormous and only an organization with an assured demand for its output can afford the investment. They must have the finest metallurgy, low-cost melting, and precision control to meet the demands for uniform quality. In my travels I saw one such

plant doing a wonderful job on high-tensile, pearlitic malleable iron to replace steel forgings. Another was doing equally well in adapting nodular iron to replace steel castings.

Managerial Problems

Whether we call it "scientific management", "engineering management" or simply "sound business", the fact remains that to be successful the future foundry must be well enough managed so it can take on the proper costs of metallurgy, research, engineering, mechanization, training, advertising, selling and cost accounting and still meet competition and wind up with a profit.

Many articles could be written on such matters exclusively. They can hardly be more than mentioned here. One of the first essentials, I would say, is a sound plan for acquiring and holding a good organization – a strong group of supervisors to run the plant and run the business. Next, the successful foundry must apply the latest engineering advances to turn out work faster, better and at lower cost. No less important is an accurate and detailed knowledge of costs by the estimators. This information is intimately connected with good accounting and budgetary practices and no less essential for establishing incentive systems for both labor and all levels of supervision and management. Production planning and production control are other essentials. Remember, tardy reports are worthless; they must be prompt enough to correct the trouble before much damage is done. Not least, but possibly most difficult, are good labor relations, which in my experience rest on fair dealing, equitable wage rates, and the constant realization that the good workman, too, is a human being with his own outlook on life and his own ambitions to achieve.

I would like to re-emphasize this thought: Don't let engineering management be an idle word. Don't think it is a one-man team. Business today is too complex for one man alone to do all the planning and all the organization. You can't win alone!

Progress in Metallurgy

We are fast coming into an era when the engineers and the metallurgists with business and practical foundry training will manage our foundries. The engineers are developing the machines, simplifying the methods, and setting the production standards. It is the metallurgist who will select materials and improve our melting process, who will specify the alloying to provide the desired characteristics in the metal, and who will plan the heat treating to meet specifications and improve machinability.

I have already mentioned two methods used by foundries to replace steel castings and forgings with iron castings. These processes will be perfected and other new ones will also be developed. Engineers and metallurgists of the customer and the vendor foundry will collaborate more closely all the time. The constant drive to make our mechanical products better and cheaper places a stiffer demand on the foundry every year. Cooperative effort is essential.

Because the production foundry will produce consistently better castings for strength, for machinability and other essential qualities, the jobbing plant that does not improve may easily go out of business or find his markets and profits restricted. The job shop owner may not be able to afford a full-time metallurgist but if he does not attend technical meetings or seek aid from his customers' technical men, his suppliers, or consulting laboratories, then his small shop cannot grow.

Progress comes from orderly research and experimentation. Progress is measured by success in making better castings, in turning them out with less labor per ton, and always at a lower cost. These were our three objectives through the years at the Campbell, Wyant & Cannon Foundry in Muskegon long before we ever began to use this word research. We grew from 3 men to 6500 men; from 3 tons per day to 1500.

I have heard many foundrymen wish they had a specialty to provide a backlog for steady operations and growth. If you can make a better casting than anyone else, you then have a specialty. But if you use research and product development to originate a specialty for your shop, and continue that research year after year to improve that product, you will have the answer to your wish for steady business and for growth.

Research can be a practical working tool for almost any foundry, no matter how small. We can and must solve our customers' problems connected with the best use of the most adaptable casting. We can search into better ways to make quality metal from whatever raw materials are available. We can cut the costs of core sand mixtures by careful study of core oils, driers, and binders. We can study alloying and heat treating for making better castings. We can do a better job for our customers than we ever dreamed of, if we set our minds to the task, and their engineers stand ready to cooperate.

A Quarter Century of Metallurgical Science

*By CYRIL STANLEY SMITH**

Chemistry was formerly the science most used to interpret the behavior of metals; the present trend is toward physics to explain metallurgical phenomena. (M general, N general, P general)

METALLURGY has two aspects – the production of metals and their application – and these relate respectively to two branches of basic science, chemistry and physics. Throughout most of metallurgical history the emphasis has been on smelting and refining, and it is natural that the chemical side of the science of metals should have matured earlier. The fine achievements of metallurgical thermodynamics of the past 25 years were a natural outgrowth of previous science. It is in the area of the physics of metals that a complete revolution has taken place during the period under review.

The most lively areas have without question been those involving physical atoms rather than chemical atoms, their arrangements in crystals and the various forms of rearrangement that occur under diffusion and mechanical forces. It has become difficult to distinguish between the researchers in metallurgy and those who call themselves solid-state physicists. Even "practical" metallurgists have become somewhat tolerant of the scientist.

There was much science in the metallurgist's training in 1930, the beginning of the 25-year life of *Metal Progress*, but it tended to be a kind of special science interpreted in metallic terms. He learned the phase rule but did not study thermodynamics. Today this is changing to an attempt to fit his special interests into the body of general scientific understanding. It is apparent that one cannot talk about any aspect of the basic science of one material without relating it to all others. Not only has the old sharp cleavage between ferrous and nonferrous metallurgy largely disappeared, but the metallurgist's approach has been applied to other solids, particularly to semiconductors and ceramic materials.

Though the emphasis on fundamental ideas is wholly admirable, a well-rounded metallurgist is not to be classed as a scientist. In addition to a considerable knowledge of theoretical physics and chemistry he must understand the art and language of the blacksmith, toolmaker and welder; he must have a keen sense of how his materials are used and the relation of their properties to service (for it is almost invariably the best combination of properties rather than a single excelling feature which is involved); he must be aware of economic and psychological factors, and of the needs of industry, government and society as a whole. Perhaps this is a definition of an engineer – such at least is the field of metallurgy, although human limitations make it impossible for any one metallurgist to master it.

In contrast to the situation a quarter of a century ago, physicists are now showing an intense interest in real solids. It is up to metallurgists to encourage them in every way possible, to learn to speak their language, and to make use of what they find out.

It is inevitable that the oldster of Hume-

*Director, Institute for the Study of Metals, University of Chicago.

Rothery's dialogue between Old Metallurgist and Young Scientist* should feel that things are passing beyond him. Somehow a wealth of practical experience with materials becomes less valuable as the framework of understanding makes both memory and new experiment easier. Let the Young Scientist remember, however, that science does not yet encompass all knowledge, and the metallurgist must be a man with a sense of reality, a sense of form, an ability to balance the scientific possibilities with economic reality and a feeling for that mass of natural phenomena that science has yet to reduce to order.

Twenty-five years ago many of the leading metallurgists were engaged in the accurate determination of constitution diagrams. The influence of Gibbs via Roozeboom and Tammann was strong, and even the practical metallurgist could see the advantage of a map of his familiar country whose principal borders were temperature and composition. Now, however, the reasons for the features on the map are beginning to be understood. Constitution diagrams are determined not only for practical ends but also – particularly by the English metallurgists Hume-Rothery and Raynor – for elucidating the contributions of electronic behavior and of atom size and configuration upon the free energies of various competing crystal structures.

The metallurgist has rightly looked for correlations in a semi-empirical fashion, but his work is closely related to the wonderful developments of quantum mechanics as applied to solids by theoretical physicists. It is perhaps odd that the peculiar behavior of "conduction" electrons – which alone distinguishes a metal from other forms of matter – was hardly involved at all in the things that metallurgists used to study. The very essence of metallicity is in conduction bands, Fermi surfaces and Brillouin zones – things with which metallurgists now have only a second-hand association, even though they work easily with mechanical models of crystals and their imperfections.

Metallurgy, Structure and Substructure

The metallographer, a generation ago the principal exponent of science in metallurgy, has been displaced from that leading position. Nevertheless, metallography is still flourishing, with recent emphasis on quantitative methods of measurement and interpretation. (In passing, one may remark that the builders of metallurgical microscopes continue in the belief that their product will by evolution give rise to a subspecies of *homo sapiens* with hands projecting from the top of the head to manipulate the stage.) The old concept of a polycrystalline metal as a foam has been revived to give a good model of grain growth. The amorphous metal boundary has come back into fashion in only slightly modified form. It is understood that many of the common microstructures of alloys with two or more phases result simply from surface tension equilibrium, almost as in a fluid system. It is realized that the mathematics of space filling are behind all the regularities and irregularities of atomic aggregates.

Metallurgists' ideas of structure have changed scale. Twenty-five years ago he attempted to explain a metal's properties by the distribution of phases visible in the microscope, although a good knowledge of the crystal lattices of many metals and alloy phases had been acquired by X-ray diffraction. For a time, the determination of atomic arrangements was the principal area of metallurgical research, but currently the emphasis is turning to structures larger than the atom but smaller than the grain.

Although courageous pioneers had attempted to show substructure in crystals, it was the dislocation theory of Orowan, Polanyi, and Taylor that provided the incentive to reconsider the whole question of the structure and strength of real crystals and the effect of deformation and annealing thereon. Yet it is probably true that informed metallurgists generally did not really *believe* in dislocations until the theory had proved itself by Shockley and Read's remarkable calculation of the energy of a grain boundary on the simplest of dislocation models, and by the spectacular mechanical properties of "whiskers" which are supposed to be dislocation-free single crystals. If further proof were needed, it is afforded by the recent etching experiments showing one etch pit per dislocation in a boundary of known angle, the lateral movement of a simple tilt boundary under shear, the observation of growth spirals on crystals, and the success of the theoretical approach in accounting for yield point phenomena.

Experimemntal knowledge of the mechanical properties of materials has increased enormously. Many studies have been done on single crystals (note the adjective which denotes their newness!) and accurate knowledge has been accumulated on the variation of strain and strain rate

*"Electrons, Atoms, Metals and Alloys", by W. Hume-Rothery; Iliffe & Sons, Ltd., London; Philosophical Library, New York.

with stress, temperature and orientation over a wide range. Despite a satisfactory qualitative understanding based on the behavior of lattice imperfections, it can hardly be said that a good general quantitative picture of either work hardening or creep exists. And despite millions of dollars spent on the brittle ship plate problem, the precise mechanism either of the origin or propagation of cracks is still obscure. Studies of one aspect of mechanical behavior – internal friction – have had a profound influence on the knowledge of the structure of metals. Principally under the stimulus of Clarence Zener, measurements of "anelasticity" have been used to elucidate slip at grain boundaries, twinning, and both interstitial and substitutional solute atoms in diffusion.

It is less than 20 years since R. F. Mehl's famous A.I.M.E. lecture on diffusion caused metallurgical investigators to make accurate measurements on many systems and to attempt to understand the phenomenon that they had used for millenia. It is only ten years since the simple experiments of Kirkendall drove home the essential difference between compositional diffusion in a lattice and in a liquid.

Structural Transformations

The mechanism of structural transformation has suffered a great deal of study. It is hard to believe that the isothermal experiments of Davenport and Bain date only 25 years back. By now, growth of phases by diffusion is moderately well understood, but nucleation of solids in solids remains a mystery (unlike solidification nuclei which have been beautifully elucidated by the group at General Electric Co.). The crystallography of the martensite transformation has been studied in many alloys, and metallurgists thereby introduced to matrix notation. Particularly important has been the scattering of X-rays to show the earliest stages of precipitation, and the realization that transitional structures exist with segregate clusters sharing interfaces with the matrix with varying degrees of compositional and structural definiteness. Nuclear resonance spectroscopy provides an entirely new tool for studying local atomic environments. It is certain to make important contributions toward an understanding of the nature of solid solutions, the early stages of precipitation, and various kinds of structural imperfections.

Another area in which the theoretical physicist has provided concepts of great metallurgical value is in the understanding of "ordered" structures – those promoters of old debates based on misunderstanding of the phase rule. Though metallurgists first observed the phenomena, it was the physicists Bragg and Bethe who developed the first simple theories of cooperative phenomena to predict the variation of degree of order with temperature. The great importance of short-range order in ordering solid solutions is just now being realized.

Magnetic Materials

The metallurgist's practical skill in developing improved magnetic materials (hard and soft) has been amply repaid by the deeper understanding of metals that has resulted. Beautiful patterns of ferromagnetic domains are sensitive indicators of stress, and just recently it has appeared that magnetic interaction between atoms even in metals that are not ferromagnetic is much more important than had been previously assumed. Atomic magnetic forces are largely responsible for the various kinds of constitution diagram of iron alloys – closed, open and drooping gamma loops – as well as providing a significant fraction of the binding energy in metals like chromium and molybdenum which are now known to be anti-ferromagnetic – that is to say, with the atom spins aligned regularly in an ordered anti-parallel fashion as distinct from the unidirectional orientation which exists within a given domain in a ferromagnetic material.

Corrosion Problems

What about corrosion? The improvement of corrosion resisting alloys has, like their initial invention, resulted from intelligent, empirical experimentation involving many trials of materials suggested more by intuition than by scientific knowledge. High-temperature oxidation is now moderately well understood as a diffusion process. In ordinary electrolytic corrosion there seems (at least to this nonspecialist author) to be a lack of understanding of the relationship between the many different factors that operate simultaneously. As in other complex fields, the structure of the interaction between simple components is at least as important as the isolated parts themselves. Inadequate consideration appears to have been given to the interfaces and the spatial relationships between anodic and cathodic areas, and of the highly localized structural features that must always determine the point at which solution commences or at which the formation or failure of a protective phase is nucleated.

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Testing, Inspection and Quality Control

By DON M. McCUTCHEON*

World War II requirements caused the transfer of testing and inspection methods from laboratory to production line and the expansion of realistic quality control. (S general)

INSPECTION and testing methods during the last quarter-century have progressed markedly – but only in a few restricted fields. Quality control programs, on the other hand, have been applied to production activities everywhere. A general prediction might be that better nondestructive inspection methods will cut costs of quality control and provide more uniform products.

In looking back over the past 25 years of testing and inspection, the writer is tempted to credit by name some of the prominent metallurgists in the automotive and parts industry. This was a period when strong personalities in the engineering departments wrote the specifications for manufacturing and purchasing. The requirements of one company were not identical with those of another and therefore many specifications existed with minor variations – most apparent in steel chemistry, wherein some of the special compositions became famous.

Many stories circulated in the early 1930's of carload lots of steel rejected on chemistry by one automotive company, but accepted as satisfactory by a competitor. The general adoption of standard analyses came naturally when the effect of chemistry on hardenability became understood. The main incentive was the savings due to the elimination of a host of fringe specialties.

New methods of testing were also associated with the rapid increase in basic knowledge about steel hardenability. Hardenability was evaluated by the simple end-quench Jominy test. Other test methods important to material and process development were based on microhardness instruments or accessories for use with optical microscopes.

Analytical testing of steel received a big boost in the late 1930's when the spectrograph evolved from a laboratory to a practical high-speed production device. Prof. O. S. Duffendack, of the University of Michigan, had developed the logarithmic sector method for the A. C. Spark Plug Div. of General Motors, and this looked promising. Two of his associates at the University of Michigan had another radical idea and the writer persuaded the Ford Motor Co. to support this research. The outcome of this work by H. B. Vincent and R. A. Sawyer was the internal standard method, now so widely used in automatic direct-reading spectrographic analysis.

Nondestructive Tests

New methods of testing the mechanical properties of metals or performance capabilities of components were introduced widely in the 1930 decade. There was a definite trend from fatigue testing of small rotating-beams to full-size components – transmissions, gears and axles in large and almost automatic machines. These expensive installations returned their cost because they checked the service records reasonably well.

One of the most interesting test methods, and one which influenced the design of many highly stressed parts such as automotive crankshafts and connecting rods, was the use of brittle lacquers in proof loading. This was followed in the mid-1930's by wide adoption of both the static and dynamic strain gage stress analysis. Weight reduction, emphasized in the design of aircraft parts and assemblies during World War II, leaned

*Technical Director, Macner Development Co., Madeira Beach, Fla.

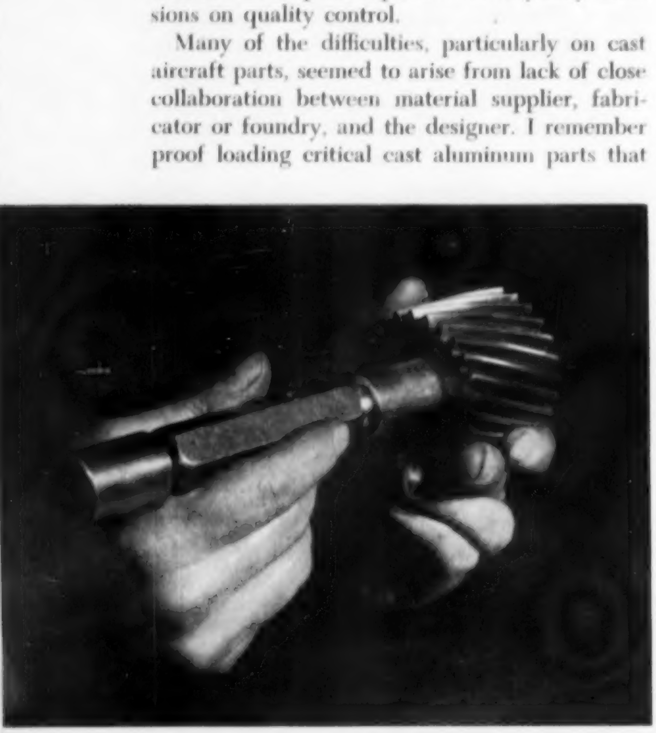
heavily upon stress analysis tests by groups who made good use of elaborate instrumentation. Early in the 1940's electrical signalling systems from high-speed rotary mechanisms had been satisfactorily devised.

In 1940 defense orders began demanding attention. Emphasis changed rapidly; testing methods formerly the sole responsibility of control laboratories now moved out into the plant. Previously, little nondestructive inspection had been performed on the production line, principally because of cost, and few of the established methods then available could meet the volume requirements of defense production.

Two nondestructive methods – magnetic particle inspection and radiography – became giants almost overnight.

Both methods suffered serious growing pains, and still bring pained expressions from engineers who recall the large numbers of parts rejected because of misapplication or misinterpretation. Quality control standards and standardized testing methods were both missing. I found myself in the middle several times on the question of sampling for test purposes and had to rely upon a personal evaluation based on very meager data. Many engineers remember how difficult it was to get field service reports on performance of aircraft or component parts so as to justify decisions on quality control.

Many of the difficulties, particularly on cast aircraft parts, seemed to arise from lack of close collaboration between material supplier, fabricator or foundry, and the designer. I remember proof loading critical cast aluminum parts that had been rejected for "severe" radiographic defects. Actually, on loading beyond design load the only thing that failed was the mounting bolts!



Magnetic particle inspection proved to be a sensitive device for detecting surface discontinuities which affect service life. Unfortunately, its sensitivity was not realized by many wartime inspectors and acceptable parts were rejected for innocuous subsurface effects – a matter clearly recognized today. Many technical societies are covering this testing procedure with specific recommendations.

Ultrasonic and Radiographic Methods

Ultrasonic testing was quite suddenly adopted in the early 1940's by many industries after almost ten years of neglect, but, like magnetic particle and X-ray methods, the interferences and unwanted effects discouraged many engineers. Since then refinements and simplification of equipment have lowered the cost of the basic unit and significantly increased its use. Again, serious problems of interpretation arose, a matter which has been vigorously attacked by the Ultrasonic Subcommittee of E-7, A.S.T.M.

During the last ten years a trend can be noted – at least on the developmental level – to semiautomatic or even completely automatic ultrasonic inspection. New techniques using shear waves, frequency modulated source and complex electronic accessories known as "B-scan" or "C-scan", are opening new applications and improving the presentation of data beyond anything believed possible during the 1930's. Despite the obvious advantages, the average metallurgist is still a little disconcerted when confronted with such an imposing array of electronic equipment.

The rapid growth of ultrasonic methods and of high-powered and portable magnetic particle inspection equipment might be expected to affect the use of radiography, but when the U.S. Atomic Energy Commission in 1946 began providing low-cost radio-isotope sources many fabricators were provided with relatively cheap equipment. Manufacturers of X-ray sets have met this competition with specialized units tailored to certain industrial needs. High-voltage betatron X-ray generators offer advantages in sharpness of image detail and thickness penetration. Unfortunately, few industries without large government contracts can afford the initial cost or provide the huge space necessary to house radiation equipment safely. Attempts have been made to show that the portable million-volt Van de Graff X-ray installation can be operated at a favorable cost.

Fluoroscopic X-ray inspection has roused some interest in the light metal field, particularly for aluminum die-cast parts where a sound surface may hide an unsound center. No significant progress has been made, however, for steel parts. Some units display the image on conventional television tubes, but commercial applications are estimated to be several years away.

Although it is impossible even to mention the multitudinous tests devised for the control of quality, something should be said about the magnetic or eddy-current method. Its merits have been the subject of considerable controversy, but the Atomic Energy Commission has shown great interest in it since about 1948. It might be said that otherwise American and English equipment had been used with only fair success; the failures caused by interfering factors outnumbered the satisfactory applications, especially on non-ferromagnetic material.

Statistical Quality Control

Prior to 1940, production inspection operations and laboratory sampling plans were in wide use. While quality limits were accepted as a necessary burden on manufacturing costs, production supervision exercised a strong voice in their interpretation. This interference was partly justified by the wholly negative character of the typical inspection procedure.

As a typical example I would cite an impact test as a proof load on a cast stress member. When the test began to throw out many castings, production supervision ordered a reduction in the proof load. This procedure was justified because the quality limits were arbitrarily chosen and the information developed by the test program had already been acted upon by foundry metallurgists. When the foundry became used to the new routines the proof load test was raised to its original value.

Most of the quality limitations during the years from 1930 to 1945 were in the nature of police actions. In fact, manufacturing operations during the war years were subjected to unprecedented policing which seemed at times to be arbitrary and unreasonable. Out of this seeming chaotic situation appeared the basis of intelligent quality control methods. Although statistical analytical methods had been applied by the Western Electric Co. and a few others prior to 1940, industry did not widely recognize them until near the close of World War II, when the high quality standards demanded by the armed services induced many companies to organize quality control sections. Sampling procedures were, for the first time, based upon well established principles of statistics. The statement is often heard that adoption of a sound sampling plan on a critical part will probably pass fewer defective parts than 100% inspection.

The literature is far too large to be covered by anyone other than a specialist.* Frequently large companies with well-established quality control departments are willing to provide fairly complete technical data on all phases of quality control. It is becoming common practice for suppliers to qualify as a certified "quality standards supplier", which is intended to eliminate dual checking and results in considerable savings in time and cost.

It is frequently said that any plant not now using quality control procedures may take advantage of these proven methods without any additional expense. This makes an excellent sales argument, and indeed – provided someone is available to set up the procedures – it is surprising how seemingly small changes in the clerical work of collecting data can often establish real control of a complex operation.

Summary

In this brief review of a quarter-century of progress in testing and quality control in industry the specialist may note many omissions. However it is hoped that the more important and controversial phases of testing have been covered. Nondestructive testing methods are still not adequate for all of industries' needs in spite of some striking advances in narrow fields. In my opinion, the engineering experience and technical training necessary for a good nondestructive testing group have been underestimated.

Quality control has made remarkable progress in the past five years, and will undoubtedly continue as the advantages become apparent in industries not now converted. One deterrent which proponents would do well to recognize is that the severely specialized language of quality control is difficult for beginners to understand.

*I am often asked for practical references that the average engineer can understand. The June issue of *Metal Progress* lists several good books and articles plus useful tables and mathematical information. Those likely to be involved in government subcontracts should know the military requirements; good starters are Military Standard MIL-STD-105A, September 1950, "Sampling Procedures and Tables for Inspection by Attributes", and Naval Ordnance Standard, No. 80, May 1952, "Sampling Procedures and Tables for Inspection by Variables".

Light Metals and Alloys

*By N. E. PROMISEL**

Aircraft have absorbed tremendous tonnages of Al, Mg and Ti; production plants are now ready for the expected demand from other industries (Al, Mg, Ti)

Of the variety of names applied to the era being commemorated by this silver anniversary of *Metal Progress*, one appropriate title is the Air Age. In that span of years military men and civilians have both turned toward air transportation. To meet this situation an enormous amount of study has been lavished on the light alloys used in aircraft, and one important by-product has been their contributions to efficiency and convenience in other applications throughout industry generally.

The periodic table contains a number of light elements. Practically all have received extensive study. For widespread use as engineering or constructional materials, however, most are soon eliminated; some are gases; some are not stable in the atmosphere; some are incorrigibly weak or brittle; some are too rare. Nevertheless, three elements of low specific gravity stand out prominently – magnesium, aluminum and titanium. They are plentiful and they can be commercially produced in usable metallic form. They are or can be rendered stable in the atmosphere and in many other common environments. Based on these elements, three great industries have emerged in the past quarter-century, reaching varying degrees of maturity, but all with great potentials for expansion.

*Head, Materials Branch and Chief Metallurgist, U. S. Navy Bureau of Aeronautics, Washington, D. C.

Very high strength per unit weight characterize all three of these metals. They don't rust like iron. Good machinability and workability generally are associated with the magnesium and aluminum alloys. The electrical conductivity of aluminum is excellent; in fact, the electrical or electrochemical properties of all three elements are useful, although for different reasons.

The element aluminum was discovered in 1825 but the aluminum industry dates back only about 70 years to the discovery by Charles M. Hall that molten cryolite dissolves alumina. This led to the practical electrolytic production of metal at least 99.9% pure. While this occurred so long before the birth of *Metal Progress* that a strong and growing aluminum industry was in existence in 1930, a 20-fold increase in production and consumption occurred during the past 25 years. This is illustrated in Fig. 1, showing that the postwar dip has been more than compensated for in the past five years. It is interesting to note in Table I how the strength of commercial alloy sheet has grown during this period.

Extrusions and forgings follow about the same

pattern as shown in Table I. The growing importance to the aircraft industry of strength at elevated temperature is reflected in the alloys formulated in recent years.

The element magnesium was isolated by chemists shortly after aluminum (in 1830), but its commercial history started only about 50 years ago. As with aluminum, electrolysis unlocked the production door and is still the major production process, even though thermal reduction, notably with ferrosilicon, has been demonstrated on a tonnage scale. The production record as shown in Fig. 2 roughly parallels that of aluminum except that in the postwar period it dropped more severely and hasn't recovered. This was undoubtedly caused by greater surplus production toward the end of the war and the greater proportion used by the military.

Table I – Growth in Strength of Aluminum Alloy Sheet

Year	Alloy	Room Temperature		Strength† at	
		Strength*	Yield*	400° F.	700° F.
1927	Clad 2017	58,000	35,000		
1931	2024	69,000	52,000		
1941	Clad 2024-T 86	70,000	66,000	26,000	5,000
1943	7075	75,000	66,000		
1951	Clad X 7178	84,000	73,000		
1952	$Al + Al_2O_3$			32,000	20,000
1953	X 2219			38,000	10,000

*Specification minimums (psi.).
†Typical values (psi.) after 1000 hr. at temperature.

The third member of our light alloy trio, titanium, is the youngest. Although its birthdate as an element in 1791 was much earlier than either aluminum or magnesium, the problem of producing it in a usable form has been so difficult that it was not solved on a production basis until 1946. The method is the well-known Kroll process by which titanium tetrachloride is reduced by molten magnesium to the pure metal. Modifications include the substitution of sodium for magnesium. Electrolytic and other methods of production have been intensively studied, with good hopes of successful conclusion. In contrast with the slow growth of the aluminum and the magnesium industry, the past nine years have seen a phenomenal increase in titanium production (Fig. 3), subsidized, it must be admitted, by the U. S. Government.

Having examined briefly each of these elements against a backdrop of the past, let us now look at the present status and future prospects for each one.

Aluminum is produced in a variety of alloys in every form – sheet, plate, bars, wire, tubes, pipes, extrusions, forgings and castings. Some of the recent significant developments include very large extrusions and forgings; close-tolerance, low-draft forgings; rolled tapered sheet and plate; and close-tolerance, thin-section castings.

Dozens of alloys have been created to meet the most specialized and diversified requirements – 6066 for sheet of high yield strength and good corrosion resistance and weldability; X 7178 for high-strength sheet and extrusions; X 7079 for large, strong forgings; 5083, 5154 and X 5356 for arc welding and XA 140 castings and X 2219 wrought products for use up to about 600° F. A whole new field has been encouraged by powder-metallurgy products made from oxide-coated aluminum powder, compacted to ingots, extruded ,and then rolled or forged; the elevated-temperature properties of this so-called APMP or SAP material have been astonishing.

Aircraft, of course, use much of the aluminum, but automotive, railroad and marine transportation also consumes considerable quantities. For example, the average 1955 passenger automobile uses approximately 30 lb. of aluminum – about 180,000,000 lb. for the 6,000,000 automobiles estimated as 1955 production. Almost a ten-fold increase is feasible for a standard car in the future. Automatic transmission parts and engine pistons are the current major uses, with colored, plated or natural-finish extruded trim, die-cast hardware, wheel rims, hub caps, radiators and even hard-tops as possible future applications. Aluminum alloys are favored for trailers and trucks wherever there are restrictions on highway weight.

Use in the electrical industry is increasing,

Table II – Minimum Specifications for Some Commercial Magnesium Alloys

Year	Alloy	Strength	Yield
1921	Cast Dow Metal	21,000	
1923	AZ 31 (cast)	23,000	
1930 to 1940	M (extrusions and sheet)	32,000	
	AZ 63 (cast)	34,000	16,000
	AZ 92 (cast)	35,000	18,000
1940 to 1950	AZ 91 (cast)	35,000	16,000
	AZ 31 (sheet)	40,000	30,000
	AZ 80 (extrusions)	47,000	33,000
	ZK 60 (extrusions)	45,000	36,000

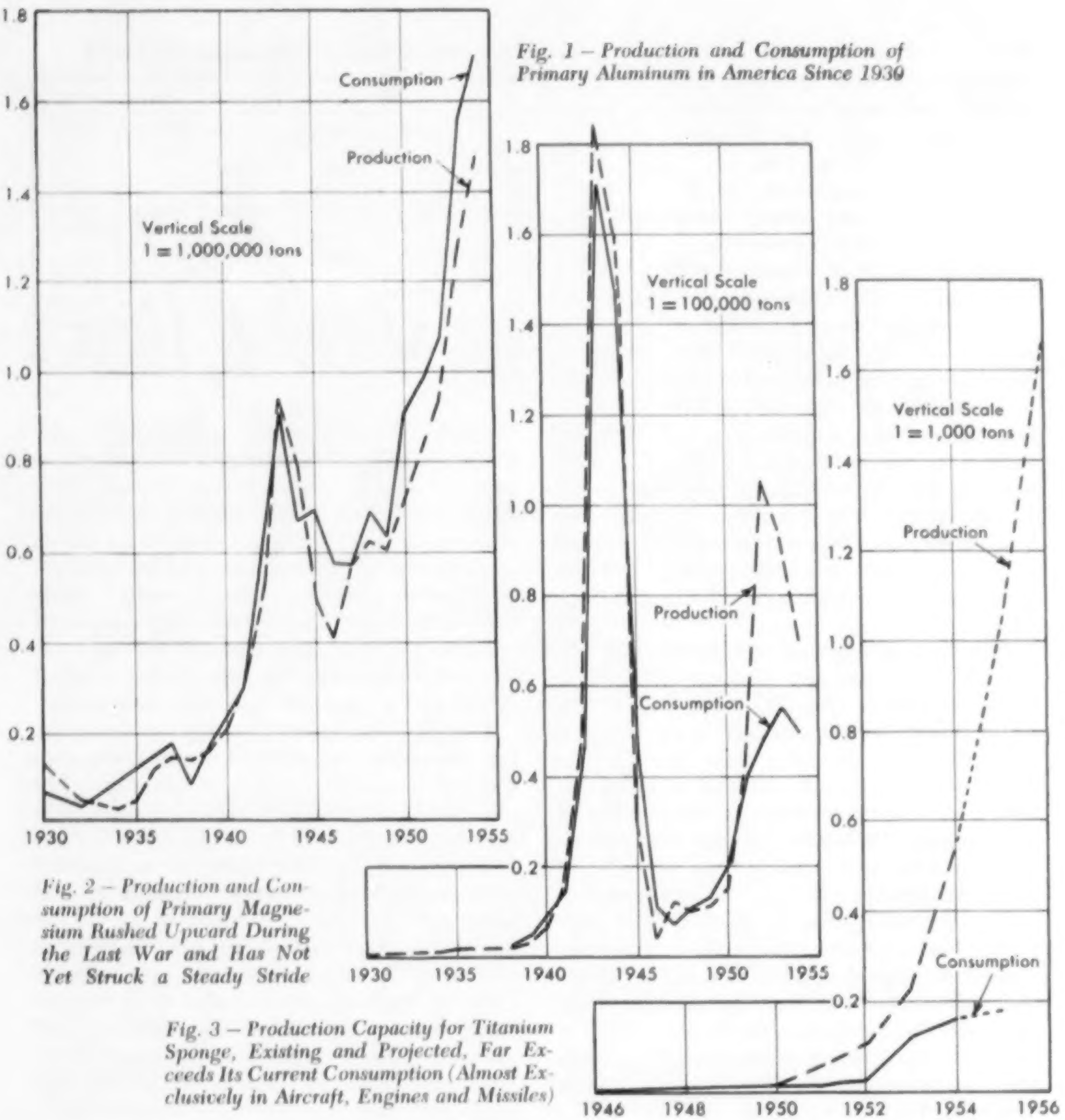


Fig. 1 – Production and Consumption of Primary Aluminum in America Since 1939

Fig. 2 – Production and Consumption of Primary Magnesium Rushed Upward During the Last War and Has Not Yet Struck a Steady Stride

Fig. 3 – Production Capacity for Titanium Sponge, Existing and Projected, Far Exceeds Its Current Consumption (Almost Exclusively in Aircraft, Engines and Missiles)

from transcontinental transmission cable to house wiring (often at less cost and greater convenience in handling). Any shortage of copper encourages the use of aluminum. Building construction, bridges, construction equipment, household and lawn furniture, food handling equipment and chemical industry equipment are other outlets of rapidly increasing importance.

Magnesium, like aluminum, is currently fabricated by practically every technique of the metal industry. Although it is produced in essentially the same variety of cast and wrought forms as aluminum, cast products account for about 65% of its use, extrusions for about 22%, and sheet for about 11%. One reason for the lower production of wrought products in recent years has been shortage of rolling mill, forging and extrusion facilities. With the emphasis on castings, significant improvements have been made in the production of large, intricate, thin-walled castings of high strength. Adhesive bonding is a significant new trend in the field of joining.

Until about ten years ago, structural magnesium alloys, both wrought and cast, consisted almost exclusively of "AZ" compositions containing aluminum, zinc and manganese. Study of a new system utilizing zinc and zirconium resulted some five years ago in the tough, high-

strength ZK 60 A extrusions. (Minimum specified strengths of some of the commercial alloys are shown in Table II.)

At about the same time, new casting alloys similar to ZK 60 A came into use, and the rare earths and thorium were added to improve properties at temperatures up to 400 and even 600° F. Wrought alloys containing thorium or rare earths (like HK 31 X A) doubtless will also be used extensively for elevated-temperature service – a matter on which major emphasis has been placed since 1950. The following are the room-temperature strengths of some promising alloys for service at 400 to 600° F. While these may seem no better than the ones listed in Table II, their strengths are maintained much better as the working temperature rises.

Alloy	Form	Ultimate	Yield
EK 30 XA	Cast	24,000	17,000
EZ 33 XA	Cast	24,000	17,000
EK 40 XA	Cast	24,000	17,000
HK 31 A	Cast	31,000	15,000
HZ 32 XA	Cast	29,000	15,000
HK 31 XA	Sheet	39,000	22,000
HK 31 XA	Extruded	43,000	38,000

A noteworthy experimental development has been the magnesium alloys containing 10 to 15% lithium. They have body-centered cubic crystal structure, outstanding strength at room and lower temperatures (48,000 psi. yield; 60,000 psi. ultimate) but are not in production because of instability and corrosion difficulties.

Impressive progress has been made in preventing the corrosion of magnesium by reducing the impurity content (especially inclusions containing the heavier metals) and by improved chemical and electrochemical surface treatments. The most notable finishing methods are the HAE alkaline anodizing process and the new Dow acid anodizing process.

The veritably limitless supply of magnesium in nature (a cubic mile of sea water contains 12 billion lb. of Mg) provides an incentive to substitute this metal for others which might be scarce during a military emergency. Previous difficulties and lack of fabricating facilities seem to be overcome. Capacity is now adequate; some plants that produced the metal for several years for the national stockpile are now in stand-by.

Although magnesium was used exclusively for military purposes during the war, last year more than half of the total magnesium consumption was in other industry. Use of sheet and extrusions for civilian applications had been hampered by lack of production facilities. Newly opened facilities mean that expansion in this field may well be expected.

Transportation industries, both air and ground, are the biggest consumers of magnesium. If the price of sheet comes down automotive use will expand. Use in air-borne equipment, including radar, has grown tremendously in the past five years and should continue to increase. Magnesium is generally present as an alloying element in aluminum alloys for aircraft and other structural applications. Consumption as alloying element represents the second largest outlet for magnesium. Growth of the aluminum industry will therefore carry with it magnesium. This carry-along function is true to a certain extent of other alloy systems such as titanium (generally produced by reduction with magnesium), nodular iron, and nickel and lead (for desulphurizing and deoxidizing).

A new use for magnesium which has grown impressively in the past decade is for the sacrificial protection of hot water tanks and heaters, oil and gas lines, ship hulls and large industrial tanks and structures. A potential related market is for dry cell casings, replacing sheet zinc. Another new field is in tooling plates for the construction of jigs and fixtures, where lightness and excellent machinability are beneficial. The printing industry has doubled its consumption of magnesium in the past year for engravers' plates, where superior etching properties permit impressive reductions in labor cost; this outlet could increase ten-fold. The following percentages show the major uses during 1954:

Structural		Nonstructural	
Aircraft and missiles	20.4%	Electrochemical and chemical	11.8%
Consumer products	2.9	Alloying	25.4
Electrical and electronic	1.1	Metallurgical	21.9
Machinery and tools	4.4	Powder	0.9
Materials handling equipment	1.8	Miscellaneous	6.7
Highway vehicles	1.5	Total	66.7%
Graphic arts	0.5		
Miscellaneous	0.7		
Total	33.3%		

Titanium

Finally, we come to the newcomer in the light alloy field, titanium. From a laboratory curiosity in 1946 to tonnage consumption for jet engine parts and aircraft sheeting, its growth is a tribute to the teamwork of industry and government. In the glowing enthusiasm so often associ-

ated with rapid progress, almost an exclusive field for titanium alloys has been predicted in the temperature range from about 300 to 800° F. This writer, though by no means underestimating its unique potentialities, is more conservative and is sensible of the competition which other materials can and will continue to offer.

Currently, titanium is being used in the form of alloy forgings for compressor disks, blades and spacer rings in jet engines. Unalloyed and alloyed sheet is used in airframes where adjacent temperatures prevent the efficient use of magnesium and aluminum or where a high-melting material is desired – for example, in ducts, shrouds, bulkheads, firewalls and skin. The next major aircraft application is expected to be for fasteners, particularly shear bolts. Numerous military applications other than aircraft have been explored and evaluated but are not in current use because of cost.

Although used only in military equipment at this time, commercial uses for titanium will emerge, particularly in the chemical industry where its outstanding corrosion resistance to difficult solutions will justify the extra first cost. The food handling industries, such as dairies, offer another promising commercial field.

Only forgings and sheet are currently available in large quantities. Welding of unalloyed titanium is under control, but only one all-alpha alloy can be arc welded. Resistance welding of alloys is practiced to a limited extent. Other fabricating processes, such as forming, drawing and machining, are practical. The deleterious interstitial elements, oxygen, nitrogen and hydrogen, now appear to be under control, although much remains to be learned of their interdependent roles in the various alloys. Scrap, although economical recovery and re-use are still serious problems, is being consumed to an increasing degree.

A Guarded Prophecy

Industrial use of any material in American mass production depends largely on cost. While there is a large spread between metal cost and cost per pound of finished articles, the trend of costs in primary ingot will give some idea of the trend in costs of usable parts for industry.

In 1930 aluminum primary ingot was 26¢ per lb. and the cost was steadily lowered to 15¢ in the mid-1940's. It has since risen almost to the 1930 price – but still it is cheap if the 70% inflation of World War II is kept in mind. Similarly for magnesium: A 47¢ per lb. ingot in 1930 was reduced to 30¢ in 1935 and further to 20.5¢ in 1945, since then rising slowly to 28¢. Grade A titanium sponge, costing $5.00 per lb. up to 1954 has dropped to $3.95 today.

Consequently in respect to cost there is nothing which will indicate any brake on future expansion of the three light metals.

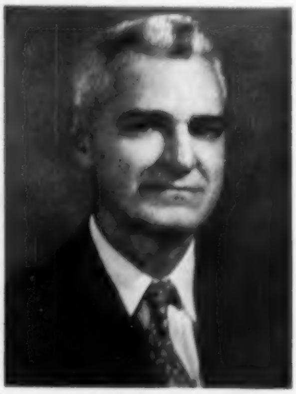
Figure I shows that the growth in consumption of aluminum, halted momentarily after World War II, has recently zoomed up like a jet interceptor. It would be hard to find any branch of the American economy which can match it. The surprisingly large postwar consumption comes from increases in civilian rather than in military demands. These are due to successful promotion of existing alloys and to refinements to meet special requirements rather than to the discovery of new ones with unusually good properties. One might expect that this situation will persist; more and more aluminum will be used for its old virtues by old industries; so much intensive research has been done already that it would be surprising if revolutionary advances in mechanical properties will appear (except possibly in the field of powder metallurgy, as mentioned above).

Enormous expansion in magnesium capacity during the War was left idle when peace came. While the production curve since 1950 is not nearly so favorable as aluminum's, the present annual figure of 90,000 tons may be compared to a tiny 6000 tons in 1940 with a good deal of reassurance. Important new facilities for wide magnesium strip and big magnesium extrusions will do much to attract the mass-production industries to this excellent metal. Likewise, it may be expected that new alloys of greatly improved properties will be forthcoming in the next decade.

Obviously, much remains to be learned about titanium alloy systems, and considerable design data, particularly at elevated temperatures, must be amassed. Improvements in alloy properties and quality are still confidently to be expected. However, the greatest single obstacle is cost. Increasingly rigid requirements for materials will dictate increased use in spite of cost, but significant reduction in production and fabricating costs should turn the consumption curve up steeply. Raw materials and production and fabrication facilities are either adequate, or obtainable as necessary. The major question in the inevitable broad expansion of this industry is "When?" Current government plans are aimed at reducing this time factor to a minimum so as to make optimum use of this important new material for military purposes.

All in all, no one but a confirmed and blinded pessimist would sell the light metals short.

Personal Mention



Norbert K. Koebel

William A. Johnson

Norbert K. Koebel was recently appointed manager of the heat treating furnace division of Lindberg Engineering Co., Chicago. He will also be chief technical advisor to associate companies in Europe and the Orient.

Prior to joining Lindberg Engineering Co. in 1940, Mr. Koebel was metallurgist for the Eastman Kodak Co., Rochester, N.Y. A graduate of Ohio State University with degrees of bachelor of chemical engineering, master of science in metallurgical engineering, and the degree of professional chemical engineer, Mr. Koebel spent one year at Battelle Memorial Institute, Columbus, Ohio, as a research fellow on the problem of controlled atmospheres. He is the author of numerous articles on controlled atmosphere heat treating, several of which have been published in *Metal Progress*. He has recently returned from an extensive lecture tour of European trade and technical societies, and while in Europe acted as technical advisor to Lindberg associate companies in Germany, France, England and Italy. Mr. Koebel is a member of the Metals Handbook Committee on Gas Carburizing, and has lectured at 32 Chapters throughout the United States and Canada. He is also a member of the American Society for Testing Materials and the American Institute of Mining and Metallurgical Engineers.

William A. Johnson has been appointed associate director, staff research and development, for Thompson Products Co., Cleveland, a position which will entail responsibility for the new chemical and metallurgical laboratory soon to be constructed. In speaking of his profession, Dr. Johnson says he "enrolled as a metallurgy student almost entirely by accident, since I knew neither metallurgists nor what metallurgists did; the selection of metallurgy seems to have been connected with a hobby of building working models out of metals." Nevertheless, he graduated from Lehigh University in 1935 with a B.S. degree in metallurgical engineering, and received a D.Sc. degree from Carnegie Institute of Technology in 1940. He was a teaching fellow in mathematics at Lehigh for a year "because there were no fellowships available in metallurgy". "This," he says, "and a year as instructor in metallurgy at Carnegie Tech convinced me that I was a very poor teacher."

His professional career has been almost entirely with Westinghouse Electric Corp., where he started in 1939 as a research fellow, becoming research metallurgist in 1941. In 1946 he was appointed manager of the metallurgical section, and later that year was loaned to the Oak Ridge National Laboratory, where he served for two years as director of the metallurgy division. Upon completion of this assignment, he rejoined Westinghouse in the atomic power division, where he was finally manager of the reactor and materials departments. Dr. Johnson received the Rossiter W. Raymond Award of the American Institute of Mining and Metallurgical Engineers in 1947, and the Westinghouse Order of Merit in 1953 for his work in connection with the atomic-powered submarine, the S.S. Nautilus. Dr. Johnson is the author of numerous technical papers dealing with diffusion, reaction kinetics and atomic energy metallurgy. He is also a member of the British Institute of Metals and the American Nuclear Society, and was a charter member of the Oak Ridge Chapter of A.S.M.

Samuel L. Hoyt, consultant for Battelle Memorial Institute, Columbus, Ohio, was recently awarded an honorary Doctor of Science degree by the South Dakota School of Mines and Technology in recognition of his outstanding contributions to engineering and science. The citation read "for his pre-eminence in the field of technical education; his notable achievements in the solution of technical problems; for his significant contributions to the development of metallurgical processes; and for his unflagging interest in the promotion and stimulation of research".

Dr. Hoyt graduated from University of Minnesota and was on the faculty there from 1913 to 1919, during which time he founded the department of metallography. He was then with General Electric Co. for 12 years, serving first as director of the metallurgy laboratory of the lamp division and later as research metallurgist. In 1931 he became director of metallurgical research for A. O. Smith Corp., and in 1939 was appointed technical advisor of Battelle Memorial Institute, the position from which he retired in 1953 to engage in consulting practice. Dr. Hoyt is known to the profession through his lectures, technical papers and books, particularly as the author of "Metals Data".

Gene R. Brehm, formerly metallurgist with Aircraft Gear Co., Fort Wayne, Ind., is now with Warner Gear Div. of Borg-Warner Corp., Muncie, Ind.

REVERE

COPPER EXTRUDED SHAPE SAVES 26% FOR TOCCO

Here is a "fishtail" and the Revere Copper Shape from which it is made. The part is a terminal block on a high frequency transformer, used in induction heating apparatus made by the Tocco Division of the Ohio Crankshaft Co., Cleveland, Ohio. Tocco is an important supplier of induction heating equipment to industry, which uses it for such diverse jobs as heat-treating and hardening, brazing, soldering, removal of gases from metal parts of vacuum tubes, vacuum casting, and heating before forging, upsetting, or other hot working.

The "fishtail" formerly was machined from solid copper bar, and on a typical run, the total cost for a certain number of pieces was $35,000. Revere studied the part with Tocco, and suggested that a shape would save money, even though the plain bar cost 10 cents less per pound. Actual experience produced these figures: total cost on the same number of fishtails, $25,700, a saving of $9,300, or 26.6%.

If your shop is machining plain rod or bar, it might pay you to consider the advantages of extruded shapes. Revere produces them in copper and its alloys, and aluminum alloys. Many design details can be preformed for you, provided they are parallel to the axis of extrusion. Revere would be glad to collaborate with you and see if shapes cannot save you money. See the nearest Revere Sales Office.

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Personals . . .

Abraham Smaardyk ⊕, formerly associate engineer in nuclear reactor design at Argonne National Laboratory, Chicago, has been appointed associate director of the expanding nuclear engineering department at Edward Valves, Inc., East Chicago, Ind., subsidiary of Rockwell Mfg. Co. At Argonne Laboratories since 1948, Mr. Smaardyk worked in nuclear engineering, covering the design of reactors, fuel technology, heat transfer, and reactor physics and experimental nuclear physics. He was associated with the Naval Reactor Division responsible for the design of ship thermal reactors, such as now installed in the nuclear submarine, S.S. Nautilus. Mr. Smaardyk was born in Middelburg, Holland, where he received his early engineering training. After obtaining a diploma in marine engineering, he sailed with the Dutch and American Merchant Marines. He is a graduate of Indiana Technical College, and received a scholarship to the Chrysler Institute of Engineering, resulting in a master's degree in automotive engineering.

R. H. Munn, Jr. ⊕ has been appointed district manager of the Pittsburgh area for WW Alloys, Inc., a division of Fansteel Metallurgical Corp.

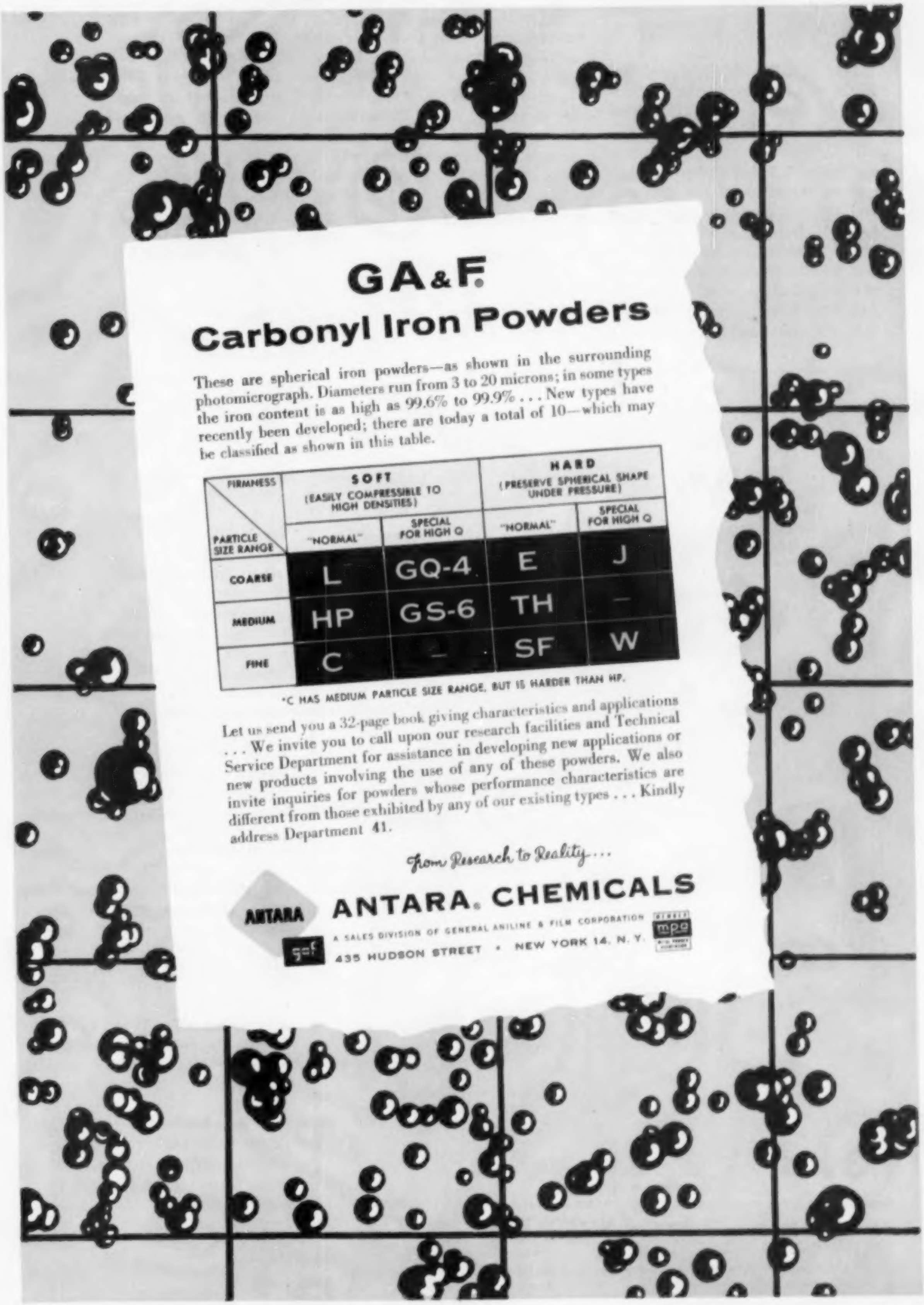
George A. Waterman ⊕ has been appointed extrusion manager for Kaiser Aluminum and Chemical Sales, Inc., Oakland, Calif. A sales and technical staff member of Revere Copper and Brass, Inc., for the past 20 years, Mr. Waterman was assistant manager of its midwest division prior to his present appointment. His educational background includes metallurgy and mechanical engineering studies at Lewis Institute (now Illinois Institute of Technology) and the University of Michigan.

Frederick C. Kroft ⊕ has been appointed general superintendent of manufacturing for Haynes Stellite Co., a division of Union Carbide and Carbon Corp. Mr. Kroft received a B. S. degree in metallurgy from Purdue University in 1942. He joined Haynes Stellite Co. in 1936, and was employed in the grinding department and later in the chemical laboratory. In 1942 he became a junior research engineer, in 1950 was named assistant technical director, and later that same year was made superintendent of the inspection, process, and quality control department. During World War II, Mr. Kroft helped to establish at Haynes Stellite a metallurgical testing group which assisted in the development of high-temperature alloys used in gas turbine blades and other applications where materials with strength and corrosion resistance at elevated temperatures are essential.

George J. Basl ⊕, for the past 14 years on the engineering staff of the heater division of Eaton Mfg. Co., Cleveland, has been appointed product design engineer for Viking Air Conditioning Div., National-U.S. Radiator Corp., Cleveland. Mr. Basl is a graduate of Case Institute of Technology.

Robert W. Krogh ⊕ was recently appointed sales manager of Ipsen Industries, Inc., Rockford, Ill. Mr. Krogh has been with the Ipsen sales staff since 1950, and during this time has served as sales engineer and district sales manager in the Detroit and Cincinnati territories.

John Crossen ⊕ is now chief design engineer for Dugway (Utah) Proving Ground, the Army Chemical Corps Testing Station for chemical weapons and ammunitions. Mr. Crossen was formerly in the Technical Services Division.


GA&F
Carbonyl Iron Powders
These are spherical iron powders—as shown in the surrounding photomicrograph. Diameters run from 3 to 20 microns; in some types the iron content is as high as 99.6% to 99.9% . . . New types have recently been developed; there are today a total of 10—which may be classified as shown in this table.

FIRMNESS / PARTICLE SIZE RANGE	SOFT (EASILY COMPRESSIBLE TO HIGH DENSITIES) "NORMAL"	SOFT SPECIAL FOR HIGH Q	HARD (PRESERVE SPHERICAL SHAPE UNDER PRESSURE) "NORMAL"	HARD SPECIAL FOR HIGH Q
COARSE	L	GQ-4	E	J
MEDIUM	HP	GS-6	TH	—
FINE	C	—	SF	W

*C HAS MEDIUM PARTICLE SIZE RANGE, BUT IS HARDER THAN HP.
Let us send you a 32-page book giving characteristics and applications . . . We invite you to call upon our research facilities and Technical Service Department for assistance in developing new applications or new products involving the use of any of these powders. We also invite inquiries for powders whose performance characteristics are different from those exhibited by any of our existing types . . . Kindly address Department 41.
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Personals . . .

Madan M. Nanda ⊕ is employed in the metal section of the development laboratories of E. F. Houghton & Co., Philadelphia.

Charles B. Buker ⊕ has been appointed supervisor of the strip mill and tin mill products section, and **Lewis U. Davis** ⊕ is now supervisor of the hot rolled, cold finished, wire, and tubular products section, product technical services, Jones & Laughlin Steel Corp., Pittsburgh. Both Mr. Buker and Mr. Lewis have been contact metallurgists for the corporation for the past ten years, serving customers in the Detroit area. Mr. Buker attended Western Reserve University, and took courses in metallurgy from International Correspondence Schools. He has been a contact metallurgist with J. & L. since 1937. Mr. Lewis attended Carnegie Institute of Technology and the University of Pittsburgh and joined J. & L. in the Pittsburgh works in 1927.

Harry S. Cummins ⊕ is a metallurgist with Norris Thermador Corp., Vernon, Cal.

Appointment of **John F. Robb** ⊕ and **Vernon H. Patterson** ⊕ to executive positions in the sales department of Climax Molybdenum Co. was recently announced by Lars E. Ekholm ⊕, manager of sales. Mr. Robb was appointed head of steel industry sales, with headquarters in Pittsburgh, and Mr. Patterson was named manager of foundry sales with headquarters in New York City. Mr. Robb has been associated with the alloy steel industry since receiving his degree as a metallurgical engineer from Pennsylvania State University in 1927. He began his career with Carpenter Steel Co., and worked in the metallurgical departments of Birdsboro Machine Co., Crucible Steel Co., and Brighton Electric Steel Casting Co. before joining Climax as a metallurgical engineer in the Canton, Ohio, office in 1935. He became manager of the Pittsburgh office of Climax Molybdenum Co. of Pennsylvania in 1945, serving also as chief metallurgist for the Langeloth, Pa., plant.

Mr. Patterson, who received his degree as a mechanical engineer at the University of Rochester in 1933, has been associated with the foundry industry since 1935 when he joined Bausch & Lomb Co. as a laboratory technician. In 1937 he was named assistant metallurgist for the company, and three years later was promoted to chief metallurgist. He became general manager of Progressive Foundry Works, Inc., in 1946, a position he held until he joined the Detroit metallurgical staff of Climax in 1949.

Neil E. Kile ⊕, formerly sales and product manager of the mechanical specialties department, has been appointed manager of the Clinton, Mass., plant of the Colorado Fuel and Iron Corp. Mr. Kile has been associated with CF&I's Wickwire Spencer Steel Div. since 1945, when he took charge of the design and installation of the plant's space cloth department.

A. R. Schneller ⊕, who has been Pacific Coast sales manager for the welding products division of A. O. Smith Corp. for the past two years, moves to the new position of eastern regional sales manager for the division, operating from the eastern electrode manufacturing plant at Leola, Pa.

Personals . . .

Tinius Olsen II was recently elected president of the Tinius Olsen Testing Machine Co., Willow Grove, Pa., succeeding his father Thorsten Y. Olsen, who was elevated to chairman of the board. The younger Mr. Olsen attended the Administration Engineering School of Cornell University, class of '35.

Cyril Stanley Smith has been granted a year's leave from his position as professor of metallurgy and director of the Institute for the Study of Metals, University of Chicago. He will reside principally in London, and will be occupied in research on the history of science. Support for the work has been given by the Guggenheim Foundation and the U. S. National Science Foundation. En route to London, Dr. Smith will attend the International Conference on Peaceful Uses of Atomic Energy at Geneva as an advisory member of the U. S. delegation.

Henry C. Ashley has been promoted at Chase Brass & Copper Co., Waterbury, Conn., to assistant director of metallurgy. Mr. Ashley joined Chase as research assistant in 1934 following his graduation from Worcester Polytechnic Institute with the degree of B.S. in mechanical engineering. In 1941 he was promoted to metallurgical engineer, the position which he held at the time of his present appointment.

R. C. Bowden, Jr. previously chemical research engineer, has been appointed assistant manager of the research laboratory of the National Tube Div., United States Steel Corp., Pittsburgh.

Richard J. Greene is in charge of International Nickel Co.'s new southeast states technical field section, development and research division, with headquarters in Atlanta, Ga. Mr. Greene joined International Nickel in February 1945 as a metallurgist on the staff of the company's research laboratory at Bayonne, N.J. Prior to his present appointment he was a member of the central Atlantic Coast technical field section in New York City. He is a graduate of Rensselaer Polytechnic Institute, holding a B.S. degree in metallurgical engineering.

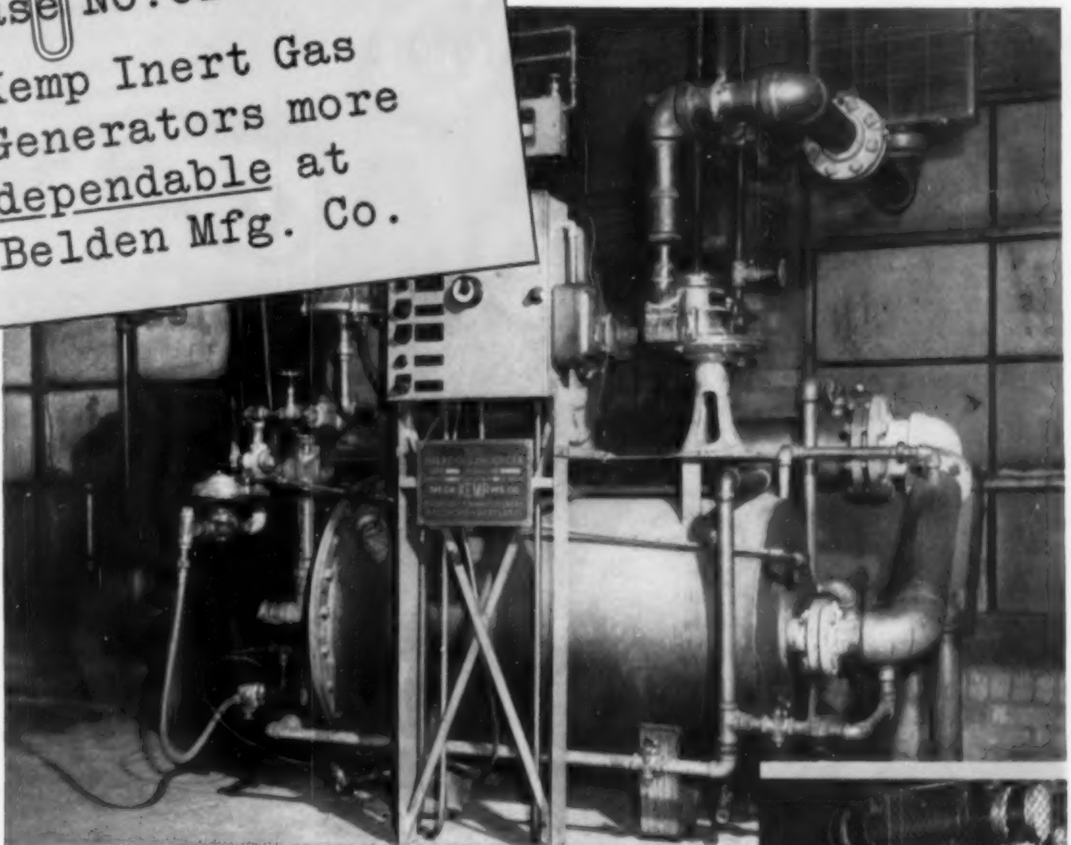
H. Stanley Thompson was recently appointed general superintendent of the Pittsburgh South Side plant of A. M. Byers Co. Joining the company in 1941 as plant metallurgist, Mr. Thompson became general inspector in 1945, and was appointed assistant general superintendent early this year. He previously had been connected with the Apollo Steel Co. in the metallurgical department, and spent several years as an instructor of chemistry and physics in the Strasburg, Ohio, school district. A graduate of Muskingum College, Mr. Thompson has done graduate work in chemistry and metallurgy at the University of Pittsburgh.

Philip Sporn, president of American Gas & Electric Co., New York, was elected vice-president of the newly formed organization, American Nuclear Society, the world's first professional organization composed of scientists and engineers engaged full-time in industrial, governmental and educational aspects of atomic energy.

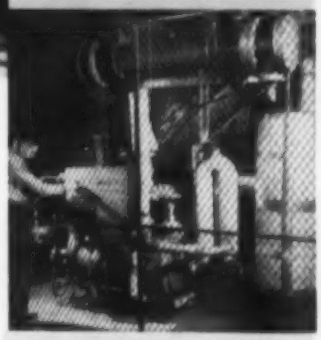
John H. Gross recently completed a tour of active duty with the U.S. Army Ordnance Corps and has accepted a position as metallurgist with the Aluminum Co. of America at the Cressona, Pa., works.

Case No. 61

Kemp Inert Gas Generators more dependable at Belden Mfg. Co.



How Belden utilizes two Kemp Generators in annealing copper wire



Generator on first floor of plant is enclosed in wire cage to prevent tampering with controls.

Annealing copper wire necessitates cooling in an oxygen-free atmosphere to prevent harmful oxidation. For the required protective atmosphere in this process, the Belden Mfg. Co., Chicago, Ill., generates its own inert gas. But the generating equipment formerly used by Belden did not operate reliably . . . results were erratic. So Belden installed two Model MIHE Kemp Inert Gas Generators to handle this important job.

And Kemp *Handles* the Job

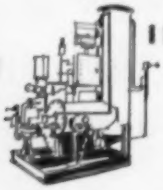
These two Kemp units assure Belden of a *dependable* inert supply. They deliver a more constant flow at the rated pressure . . . have been operating smoothly and satisfactorily since installation. Kemp's ability to produce a chemically clean inert at a *specific analysis regardless of demand* eliminates the danger of fluctuation at a critical stage.

Kemp Units Engineered for Service

Like Belden, you specify reliability when you specify Kemp. Every Kemp design includes the Kemp Industrial Carburetor for complete combustion without tinkering, without waste . . . for simplified installation and maintenance. Every Kemp design includes the very latest fire checks and safety devices. Annealing, hardening, sintering—whatever your problem, find out today how Kemp engineers can help you.

For more complete facts and technical information, write for Bulletin I-10 to: **THE C. M. KEMP MFG. CO., 405 East Oliver Street, Baltimore 2, Md.**

KEMP OF BALTIMORE



INERT GAS GENERATORS

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METAL MELTING UNITS · ADSORPTIVE DRYERS
SINGEING EQUIPMENT

Personals . . .

C. Roger Sutton ⊕, senior metallurgist at the Argonne National Laboratory of the U. S. Atomic Energy Commission for the past five years, has joined the development and research division of the International Nickel Co., Inc., as a member of the stainless steel and heat resistant alloys section. Before his association with Argonne National Laboratory in 1950, Mr. Sutton had served for five years as general consultant, and immediately prior thereto was director of engineering and metallurgy for General Alloys Co., Boston.

Walter S. Baker ⊕ has been appointed sales manager of the Hartford, Conn., district of the Universal Div., Universal-Cyclops Steel Corp. **F. F. Harter** ⊕, who for many years has held this post, will continue as special representative.

Kenneth A. Honroth ⊕ was recently elected president of Freeway Washer & Stamping Co., Cleveland. Mr. Honroth is one of the founders of the company, and has served as an officer for 11 years.

William G. Fricke, Jr., ⊕ and **M. Scott Hunter,** of the research laboratories of Aluminum Co. of America, New Kensington, Pa., have received the Richard L. Templin Award of the American Society for Testing Materials for their paper, "The Metallographic Aspects of Fatigue Behavior". Mr. Fricke, research metallurgist, received his B.S. degree from Pennsylvania State University in 1951, and has been with Alcoa since 1952.

Robert H. Kaltenhauser ⊕, **John E. Mosser, Jr.** ⊕, and **David L. Raymer** ⊕, research metallurgists, have been added to the technical staff of the Allegheny Ludlum Steel Corp.'s research laboratory in Brackenridge, Pa. Mr. Kaltenhauser received his degree in metallurgical engineering from the University of Cincinnati in 1953. Mr. Mosser is a 1955 graduate of Pennsylvania State University, with a B.S. degree in metallurgy, and Mr. Raymer received his B.S. degree in metallurgical engineering from Carnegie Institute of Technology in 1955.

Personals . . .

William D. Gilder was recently appointed chief metallurgist of Reed Roller Bit Co., Houston, Texas. Mr. Gilder received his B.S. and M.S. degrees from Notre Dame University and Carnegie Institute of Technology, respectively, and prior to his present appointment was chief metallurgist for the Weatherhead Co., Cleveland.

Carl B. Post has been promoted to vice-president in charge of metallurgy at the Carpenter Steel Co., Reading, Pa. Dr. Post, a member of the metallurgical staff since 1938, was named chief metallurgist of Carpenter Steel in July 1951, and since that time has been head of the metallurgical and research departments. He is known for his research in the fields of automotive and aircraft valve steels, and especially for his work on the alloying of nitrogen with these steels for better workability and greater strength at high temperatures. His most recent contribution has been in the use of rare earth elements such as cerium and lanthanum to improve the hot workability of corrosion resistant and heat resistant alloys.

Arthur Townhill has joined the Harwill Corp., Los Angeles, as director of engineering. Mr. Townhill's engineering, production and scientific background spans more than 30 years, including two decades with Thompson Products, Inc., Cleveland, where for ten years he was chief engineer and manager of the light metals division. Immediately prior to his present appointment, Mr. Townhill was assistant project director at Alloy Engineering & Casting Co., Champaign, Ill. A graduate of Case Institute of Technology, he holds 11 patents on pistons, fittings and casting machines. In 1953 Mr. Townhill traveled to Germany to study advanced forging and casting methods.

Robert W. Stoddard, president of Wyman-Gordon Co., Worcester, Mass., was recently elected chairman of the board of Prex Corp., Chicago.

Donald F. Stoneburner, a graduate of the University of Cincinnati, has been appointed to the staff of the Oak Ridge National Laboratory, Oak Ridge Tenn., an atomic energy installation operated by Carbide and Carbon Chemicals Co., a division of Union Carbide and Carbon Corp.

George V. Smith, research metallurgist with the United States Steel Corp. research laboratory in Kearny, N. J., has received an appointment to the Francis Norwood Bard Professorship of Metallurgical Engineering at Cornell University. Dr. Smith was graduated in 1937 from Carnegie Institute of Technology, and received his Ph.D. degree there in 1941. Since 1948 he has taught graduate night courses in metallurgy at Brooklyn Polytechnic Institute. Dr. Smith has written many technical articles as well as the book "Properties of Metals at Elevated Temperatures".

S. B. Knutson, formerly superintendent for National Electric Products Co., Ambridge, Pa., is now plant manager for Kidd Drawn Steel Co., West Aliquippa, Pa.

Personals . . .

John A. Rassenfoss has been appointed manager of the manufacturing research laboratory of American Steel Foundries, Chicago. **C. G. Mickelson** has been appointed assistant manager.

William W. Sieg, president of Titan Metal Mfg. Co., Bellefonte, Pa., was recently presented the Distinguished Alumnus Award of the Pennsylvania State University. The honor was conferred upon Mr. Sieg for his "thorough knowledge of the brass and copper industry which has won him an outstanding reputation in the business world and made him a valuable consultant to the United States Government". Mr. Sieg was previously honored by Penn State with the David Ford McFarland Award for attainment in the metallurgical industry.

E. J. Boyle recently became a member of the metallurgical staff at Electro Metallurgical Co., Niagara Falls, N. Y.

Olaf G. Paasche has returned to his position as associate professor at Oregon State College after completing graduate work at the Illinois Institute of Technology.

Robert Bakish received his doctorate in metallurgy from Yale University in June, and is now employed as a senior engineer with Sprague Electric Co., North Adams, Mass. Dr. Bakish's duties will consist of organizing a metallurgy laboratory and work in research and development of materials for electronic components.

Lyle M. Barnard is employed as college trainee in the physical metallurgy section of the department of metallurgy, Kaiser Aluminum and Chemical Corp., Spokane, Wash.

Francis Beaupre, formerly manager of Barber-Colman of Canada, Ltd., Toronto, is service manager and application engineer for Wheelco Instruments Div. of Barber-Colman of Canada, Ltd., Chicago.

William H. Magnuson has been transfered by the Dow Chemical Co. from Midland, Mich., to the Detroit sales office where he is representing the magnesium department as sales engineer.

Personals . . .

Carson L. Brooks ⊕, formerly assistant chief, process metallurgy division, Aluminum Research Laboratories of Aluminum Co., of America, New Kensington, Pa., is now assistant director of metallurgical research, metallurgical research laboratories, Reynolds Metals Co., Richmond, Va.

Albert M. Barloga ⊕ is a trainee in the quality control department of Inland Steel Co., Chicago.

Guntars Sulcs ⊕ is employed as a trainee for American Smelting and Refining Co., Whiting, Ind.

J. Bruce Ferguson ⊕, previously in the technical department, International Nickel Co., Inc., Bayonne, N. J., is now employed as project superintendent in the foundry division of Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Lloyd F. Lockwood ⊕, who received his M. S. degree in metallurgical engineering from Ohio State University in June, is employed as a research and development engineer in the wrought section of the magnesium department at Dow Chemical Co., Midland, Mich.

Anson B. Albree ⊕, formerly with Rolled Alloys, Inc., Detroit, is sales manager for Aluminum Foils, Inc., Jackson, Tenn.

John E. Eydt ⊕, who graduated in metallurgy from the Ryerson Institute of Technology, Toronto, is employed in the metallurgical research and development division of the Steel Co. of Canada Limited, Hamilton, Ont.

Tak Matsuda ⊕, formerly civilian supervisor of Technical Liaison Office, Far East Air Forces, is now a research engineer in the material and process group, North American Aviation, Inc., Los Angeles.

Emmett Smith ⊕, formerly assistant chief engineer of the electrode division of Lincoln Electric Co., Cleveland, has been promoted to chief engineer. Mr. Smith joined the engineering department of Lincoln Electric immediately upon graduating from Ohio State University as an electrical engineer in 1928.

John A. Misencik ⊕ has resigned as experimental metallurgist at the Cadillac plant of General Motors Corp., Cleveland, and is employed as a metallurgist in the artillery section of the materials engineering branch, Watertown Arsenal, Watertown, Mass.

William Fortune Smith ⊕, having received his M. S. degree in metallurgical engineering from Purdue University, is now working as a metallurgical development engineer at the Arvida Works of the Aluminum Co. of Canada.

Morton S. Cecil ⊕ has been transferred from development work at the Savannah River Plant to a position as personnel assistant in the college relations section of personnel employee relations department, E. I. du Pont de Nemours & Co., Wilmington, Del.

Edwin J. Silk ⊕, formerly with A. Milne & Co., New Britain, Conn., is now associated with K. & S. Metal Supply Co., Long Island City, N. Y.

Harold J. Smith ⊕ recently resigned as assistant works metallurgist at International Harvester Co.'s farm tractor plant, Louisville, Ky., to accept a position as corrosion engineer in the metallurgy and ceramics section of the major appliance laboratories of General Electric Co. in the same city.

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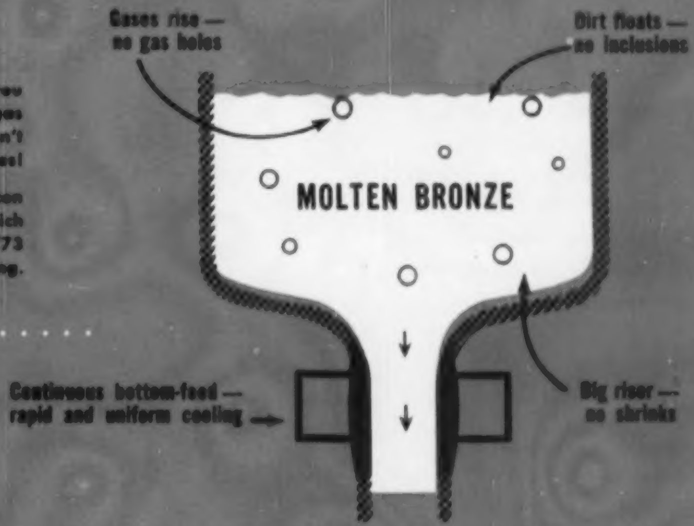

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Fatigue Tests on British Wrought Steel

SIXTEEN years ago an investigation of the effect of inclusions on the fatigue of steel was started by the Inclusions Subcommittee of the British Iron and Steel Institute and the results are now being reported. The stock used for the tests consisted of bars rolled from steels made in basic electric, basic openhearth, neutral openhearth, and acid openhearth furnaces. No chemical compositions are given in this paper, but the bars were heat treated to tensile strengths of about 135,000, 180,000, and 246,000 psi. respectively. The cleanness of the steels was evaluated by Fox inclusion counts, and the kinds of inclusions present were also noted. Fatigue tests were made on both longitudinal and transverse specimens by the Wohler rotating beam method. The specimens were shaped so as to be stressed uniformly for a length of 1 in. Metallographic examinations were made at many of the fractures.

The results showed little difference between the longitudinal and transverse strengths, but in elongation and fatigue limit the transverse results were about 25% lower. For the steels of 135,000 psi. tensile strength the longitudinal fatigue limits were 70,600 to 75,000 psi., and transverse 53,800 to 65,000; for those (only two) of 180,000 psi. tensile strength the fatigue limits were about 93,000 longitudinal and 65,000 transverse; and for those in the 246,000-psi. strength range, 81,000 to 105,000 longitudinal and 60,500 to 67,000 psi. transverse. Thus, no consistent advantage in fatigue resistance of longitudinal specimens was attained by raising the tensile strength above 180,000 psi., or in that of transverse specimens above 135,000 psi.

The Fox inclusion ratings of these steels ranged from 28 to 104, without any apparent correlation with fatigue strength. Since the higher inclusion ratings were due chiefly to higher sulphur contents (up to

(Continued on p. 168)

*Digest of "Fatigue Tests on Rolled Alloy Steels Made in Electric and Open-Hearth Furnaces—Part I", by P. H. Frith, *Journal of the Iron and Steel Institute*, Vol. 179, May 1955, p. 26-33.

Fatigue Tests . . .

0.04%) it is concluded that sulphides do not affect the fatigue strength. Although it is stated that no definite correlation was found between the fatigue test results and the types of inclusions present, the metallographic studies appear to indicate that the longitudinal fatigue limit of the specimens heat treated to 246,000 psi. tensile strength was reduced at least 17% by silicate or other inclusions that were not deformed in the rolling operation.

Out of 15 test specimens which showed inclusions on the critical surface before fatigue testing, only one started its fracture at a surface inclusion. Inclusions just below the surface appeared more detrimental to the fatigue resistance, especially in steels heat treated to 246,000 psi. tensile strength. White circular areas, due to very slow fracture propagation, were visible in the fractures around the inclusions from which the fractures started. Most of the inclusions located at the origins of fractures were silicates or duplex inclusions containing silicate. In the electric steel these inclusions deformed less in rolling than in the openhearth steel, and among the steels of high strength (246,000 psi.) the electric steel had a lower longitudinal fatigue limit (81,000 to 91,000) than the openhearth (100,000 to 105,000 psi.), possibly for that reason. G. F. COMSTOCK

Alloys in Ti-Sn and Ti-Al Systems*

THE FIELD of the alpha-plus-beta phase was described by A. D. McQuillan in 1951 for the titanium-rich portions of the Ti-Al and Ti-Sn systems using the hydrogen-pressure method. Published phase diagrams show that additions of aluminum to titanium cause a progressive increase in the alpha and beta transi. Conflicting results, however, have been published on the effect of tin on the

(Continued on p. 170)

*Digest of "A Study of the Behavior of Titanium-Rich Alloys in the Titanium-Tin and Titanium-Aluminum Systems", by A. D. McQuillan, Journal of the Institute of Metals, Vol. 83, 1954-55, p. 181.

Titanium Alloys . . .

transformation. In previous work on both systems, few alloys have been examined adjacent to the titanium end of the diagram; objective of the present investigation was to determine accurately the form of the alpha-plus-beta region in the two systems over a limited range of titanium-rich compositions.

The alloys were prepared by arc melting in an argon atmosphere using iodide titanium that contained 0.2 at.% (0.38% by weight) zirconium as the only significant metallic impurity. The aluminum or tin used for alloying was of 99.9% purity. The ingots of titanium-aluminum alloy were forged at 700° C. (1290° F.) into bars and homogenized in vacuum for 100 hr. at 1000° C. (1830° F.) and the titanium-tin alloys at 940° C. (1725° F.).

In the hydrogen-pressure method, a small quantity of hydrogen amounting to about 0.05 at.% is dissolved in an alloy specimen contained in an enclosed system, and the equilibrium hydrogen pressure, p, that is set up is measured as a function of temperature. A linear relationship between $\ln p$ and $1/T$ (where T is the absolute temperature), indicates that the alloy is single phase. In the two-phase region, the relation between $\ln p$ and $1/T$ gives a smooth curve.

The results of this investigation of the titanium-aluminum systems and those of Bumps, Kessler, and Hansen (*Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 200, 1954, p. 548) obtained by metallographic examination of quenched alloys, are shown in Fig. 1 (solid lines are McQuillan's data).

The experimental error in determining the phase boundaries by the hydrogen pressure method is about 2° C. (3.6° F.). The author's results show a slight dip in the alpha-beta phase region below about 4 at.% that was not revealed by previous investigations. However, Bumps and coworkers examined alloys only at 900° C. (1650° F.) in this range of composition and their findings at this temperature are entirely consistent with the present more detailed results. The results were found to be abnormally sensitive to the

(Continued on p. 172)

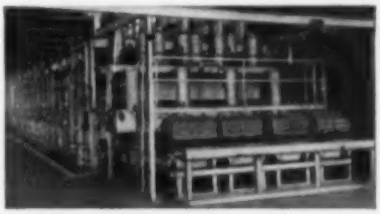
How to Select the Most Economical Insulating Firebrick

The advantages of lightweight insulating firebrick over ordinary "heavy-weight" firebrick are generally known to furnace operators and furnace builders. But many buyers have wondered just what advantages there might be in one brand of insulating firebrick as against another. The answer to this question could very well mean savings in fuel costs, increased furnace output, longer life . . . or all three.

One furnace builder ran tests on their small electric kilns where heat input could be measured with great accuracy. Here's what they found: B&W IFB required 25% less heat than any other brand of insulating firebrick they tried.

The reason? B&W IFB are lighter in weight than any other insulating firebrick — they contain more tiny, insulating air cells. Heavier, denser insulating firebrick linings waste fuel two ways: They soak up and store more heat which is lost when the furnace is cooled; and they conduct more heat through the walls.

How about long life? One of the



toughest tests of firebrick is in the lining of a carbon monoxide furnace. Some brands last only a few weeks, then disintegrate, due to iron oxide impurities in the brick which react with the gas.

But B&W Insulating Firebrick contain little iron oxide, and they're processed at high temperatures so that any traces of iron oxide form stable compounds. So instead of deteriorating they stay on the job year after year —in many cases over 10 years.

Another factor, important to many furnace operators, is accurate temperature control. Here again B&W IFB have an advantage over other insulating firebrick. First, because B&W IFB are lighter in weight they store and conduct less heat—and they respond more quickly to changes in heat input.

A typical example is the giant stress-relieving furnace shown below—sixty feet by twenty-two feet by seventeen feet high. The B&W lining plays a vital part in holding the desired temperature within 5 degrees accuracy!

Next time you buy or specify insulating firebrick, remember that the lightest weight brick of all—B&W—has the highest insulation value, the longest life and the greatest furnace heat controllability.

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Titanium Alloys . . .

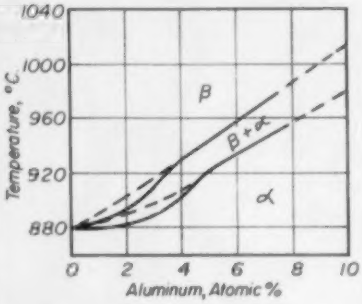

Fig. 1 – Phase Relations for Titanium-Aluminum Alloys, According to the Author (MacQuillan – Dotted Lines) and to Bumps, Kessler and Hansen

hydrogen content of the alloys in the region of the dip. The author suggests that the dip may be caused by a very small change in the stability of the alpha phase up to about 4 at.% aluminum.

The results of the investigation of the titanium-tin system are shown in Fig. 2.

A minimum point in the alpha-beta field was found at 6.5 at.% tin

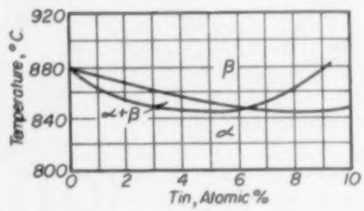

Fig. 2 – Phase Relations for the Titanium-Tin System

and 845° C. (1550° F.). These results differ from those of Worner in that no trace was found of a discontinuity due to the peritectoid horizontal reported by Worner to occur at 885° C. (1625° F.) in alloys containing more than 8 at.% tin.

Anomalous deviations from the linear curves occurred in alloys containing between 3.5 and 8 at.% tin at temperatures above 960° C. (1760° F.) and below 700° C. (1290° F.). At a temperature ranging from 640 to 690° C. (1185 to 1275° F.), depending on the alloy composition, the specimens exhibited an isothermal increase in hydrogen pressure which continued until the greater part of the hydrogen initially dissolved in the specimen was ex-

pelled. Metallographic examination revealed no change from the single-phase nature in the temperature range of the isothermal increase in hydrogen pressure. A resistivity-versus-temperature curve showed no discontinuity in slope in the temperature regions in which the anomalous hydrogen-pressure relationships were observed.

The systems of titanium with chromium, manganese, iron, cobalt, and nickel exhibit a remarkable limitation of alpha-phase solid solubility while having very extensive solubility in beta. The author reasoned that an investigation of the extensive alpha-phase solubility in systems such as titanium-aluminum and titanium-tin might contribute toward an understanding of the very limited solubilities of the above beta-stabilizing elements in alpha titanium. At present, however, no reason is yet evident for the extensive alpha solubility of aluminum and tin. Therefore, further investigations are being carried out on the electrical resistivity composition relationships in the alpha solid solution regions of these two systems and also on the change in heat of solution of hydrogen in titanium with concentration both of dissolved hydrogen and metallic addition elements.

R. J. McClintick

Desiliconizing in Basic Openhearth Furnaces*

Openhearth operations and production rates are greatly affected by the analysis and temperature of the hot metal, which amounts to 40 to 70% of the total metal charge. It has long been known that high silicon, over 1%, in the hot metal has a highly detrimental effect on output on account of the need for higher charges of ore and lime, and more sluggish reactions resulting from such a charge. Fuel consumption is higher because the large slag volume absorbs heat and also limits the amount of hot metal which may be charged in any given heat. Usually 40% hot metal is the best with pig

*Digest of "Desiliconized Hot Metal in Basic Openhearth Furnace", by L. M. Billimoria, T. V. S. Ratnam and S. N. Anant Narayan, *Technical Journal* of the Tata Iron and Steel Co., Vol. 2, January 1955.

Desiliconizing . . .

irons containing about 1.25% silicon.

Various writers on this subject have stated that average temperatures of hot metal from the mixer are between 2450 and 2500° F. This metal has to be raised above 2900° F. in the furnace and the scrap charge must be nearly melted (2800° F.) before hot metal of this temperature may be charged. When hot metal of a higher temperature is available it may be charged much earlier and the refining reactions proceed much more rapidly. The authors give a fine review and bibliography on this subject.

Large increase in the alumina content in iron ores charged into the blast furnaces at Tata Iron & Steel led to consideration of the desiliconizing of hot metal in this openhearth. Blast furnace slags at Tata have Al_2O_3 contents of 26 to 28% and the high viscosity of these slags limits the amount of calcium oxide that can be carried. As a result the lime-silica basicity has dropped from 1.4 to 1.2, with higher silicon content resulting in hot metal. The tabulation indicates the detrimental influence this high-silicon hot metal has on operations in the basic openhearth:

Year	Stone	Lime	Ore and Scale
1945	154*	38*	74*
1948	178	39	84
1949	190	27	106
1950	233	24	140
1951	225	22	129
1952	224	32	111

*In lb. per ton of steel

With a 45% hot metal and 55% scrap charge, the time for each heat in this plant was 15 to 16 hr. for 100-ton heats; melting rate per hour of about 6 tons was about half of that normally expected in America for similar charges. The desiliconizing of hot metal was introduced with the idea of improving operations in three respects:

1. Increasing the percentage of hot metal in the charge so that less cold scrap would be used with an attendant decrease in charging time and fuel requirement.

2. Desiliconizing of hot metal in order that increased percentage of hot metal could be charged with de-

(Continued on p. 176)

Desiliconizing . . .

creased slag column, limestone, and iron ore.

3. Providing a supply of hot metal of more uniform analysis and higher temperature.

After reviewing previous papers on the desiliconizing of hot metal in iron ladles and mixers, the authors concluded that these methods would not be applicable in their plant. No mention is made of using a converter for desiliconizing. It was finally decided to take one of the eight openhearth furnaces for this purpose. After several trial runs made by blowing 100-lb. pressure oxygen by a lance into 55 tons of hot metal into the openhearth furnace used as a desiliconizer, this furnace was used exclusively to produce low-silicon hot metal. The first trials showed that 55 tons of hot metal could be desiliconized in about 28 min. from 1.12 to 0.36% Si with an oxygen efficiency of about 85%. In actual operation 3 tons of limestone and 2 tons of iron ore were charged on the furnace bottom, then the 100-lb. pressure oxygen was blown for 25 to 30 min. The treated metal was then tapped in a 50-ton ladle to permit the slag to overflow into a slag pot. This desiliconized metal was then transferred to another openhearth furnace as a 55% hot metal charge. It was found that carbon only dropped from 4.18 to 3.90%, manganese from 0.48 to 0.20%, and phosphorus from 0.33 to 0.26%.

Since the rate of producing desiliconized hot metal in one furnace was insufficient for the seven other melting furnaces, a composite charge of about 25% regular hot metal, 75% desiliconized hot metal was finally chosen for a full plant test lasting 25 days. The charge used during the period was:

	Tons	
Cold scrap	3955	43%
Regular hot metal	1784	
Desiliconized metal	4766	
Total hot metal	6550	57
Limestone	902	7.8
Iron ore (charge)	370	3.2
Feed ore	208	1.8

The average silicon content of the desiliconized hot metal was about 0.45% as compared to an average of 1.25% on regular hot metal. The

(Continued on p. 178)

another case where

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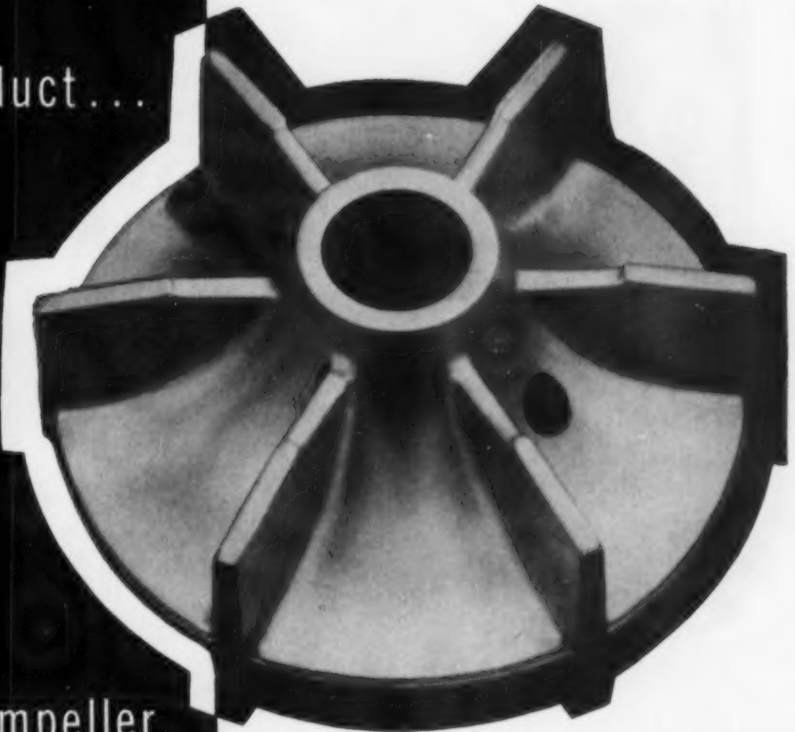

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temperature of the hot metal was raised 392° F. by desiliconizing.

The gross tons per hour output of the furnaces increased from 6.00 to 6.81 tons per hour. Scrap charging time was reduced from 5 hr., 10 min. to 3 hr., 22 min.

Conclusions – Desiliconization of blast-furnace hot metal has been carried out and controlled in a stationary basic openhearth furnace with the help of oxygen. The success of these experiments is due to the normal bath depth of about 30 in. of the furnace used for desiliconization.

By introducing part of the oxygen as solid oxides (iron ore and scale) and supplementing the balance by gaseous oxygen, the time needed for desiliconization is decreased considerably. The oxygen lance helps in dissolving the solid oxides in a short time and in accelerating the reactions. If, for instance, 20,000 cu.ft. of oxygen is to be lanced, it would require about 50 min. at the rate of 400 cu.ft. per min. and another 10 min. for changing lances, bringing the total time required for lancing to 2 hr. On the other hand, if 15,000 cu.ft. of oxygen is introduced as solid oxides and only 5,000 cu.ft. is lanced, the time required would be 15 to 20 min. In case of desiliconization of ladles, it will not be possible to charge such a proportion of solid oxides and dissolve them to bring about an efficient reaction.

No difficulty is encountered in the form of fumes or splashing, as is common with ladle desiliconization with oxygen, when special hood and suction arrangements become necessary. Further, the shallow bath of the stationary furnace helps in attaining high chemical efficiency.

The amount of metal that can be treated at a time depends on the size of the furnace, and this method has a distinct advantage over the treatment in ladles, where only 20 to 30 tons can be desiliconized.

The slag formed is easily got rid of by allowing it to overflow from the ladle while tapping. Since the experiments were conducted in a stationary furnace with 50-ton charges, the ladle capacity was kept at just 50 tons, so that all the slag

(Continued on p. 180)

Desiliconizing . . .

would overflow. This can be further simplified by employing a tilting furnace.

The throughput of a 400-ton active mixer is about 2500 tons per week on the basis of 1.2% silicon in iron going in and 0.3% silicon in iron going out. With the process described in this paper, a 50-ton tilting furnace would easily give this throughput.

E. C. WRIGHT

Thermal Stress Fatigue in Austenitic Stainless*

FATIGUE FAILURES of austenitic stainless steels are often produced by a relatively limited number of thermal stress cycles under conditions of high cycling temperatures. Data are required for understanding the mechanism of failure and for predicting material behavior.

The test apparatus used in these experiments constrained a thin-walled tubular test specimen at each end and the specimen was alternately heated and cooled to produce the desired uni-axial cyclic stresses. Because of the end constraint, both elastic and plastic strain are reversed and a hysteresis loop is developed. The strain change for a given temperature cycle remains fixed but the stress change varies as the properties of the specimen change. It was found that increasing the cyclic temperature change decreased the number of cycles to failure. In general, failure was found to depend on the total accumulated plastic strain; and an empirical relationship between the number of cycles to failure and the plastic strain change per cycle was established.

The relationship is dependent on the type of material, its heat treatment, degree of cold work and numerous other factors. Of primary importance is the localization of strain concentration produced by the structural design of the thermally cycled material. An example of such

Continued on p. 182)

*Digest of "The Problem of Thermal Stress Fatigue in Austenitic Steels at Elevated Temperatures", by L. F. Coffin, Jr., American Society for Testing Materials, Special Technical Publication No. 165, October 1954, p. 32-50.

Thermal Stress . . .

strain concentration is the dovetail slots used for attaching turbine blades to rotors; this strain concentration, of the "parallel" type, exists at the root of the slot. Another example is a constrained column with a reduced diameter over a small fraction of its length. The reduced area section bears a higher stress and strain which can cause failure in a limited number of cycles. This is known as "series" type strain concentration.

Strain concentration can also be produced by variations in material. For example, a column constrained at both ends might consist of different materials in series. Under thermal cycling, both materials are subjected to the same stress but, depending on the properties of the two materials, their respective deformation and their cyclic plastic strain might be considerably different. This would accelerate failure in one material.

The experimental equipment was used to test the effect of strain concentration during thermal cycling. One sample was a thin-walled tubular specimen with a 0.040 in. hole drilled diametrically through the tube at its midpoint. The area around the hole was examined during the thermal cycling and the test was terminated when a crack had propagated over a considerable portion of the cross-sectional area. Failure occurred at approximately one-tenth the number of cycles withstood by the uniform tube.

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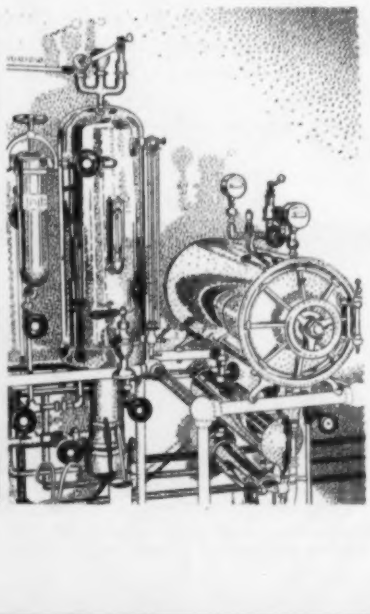


Thermal Stress . . .

A series of tests was also made using a 3/16-in. diameter rod which had been cold worked over only a part of its length. This was accomplished by twisting the specimen after a portion of it had been reduced to its final diameter. The thicker portion is not significantly cold worked by the twisting and after it is reduced to the final diameter, a specimen with a material discontinuity is produced. The effect of this discontinuity was quite marked. Two specimens with no discontinuity failed after more than 2000 cycles, while specimens with 12.5% of their length annealed and the balance cold worked failed after about 300 cycles. These test pieces were strain cycled at a temperature of 350° C. (660° F.). The specimen was maintained at temperature and cycled to maintain a total strain change per cycle of 1% over the 1-in. gage length.

A comparison was made for similar specimens thermally cycled under constrained conditions and strain cycled at a constant temperature equal to the average temperature for the thermal cycle. Identical cyclic strains were compared, the difference being only in the temperature. For the thermal cycling the temperature was cycled between 100 and 600° C. (212 to 1110° F.). In the strain cycle the average temperature of 350° C. (660° F.) was maintained. These tests indicated that the number of cycles to failure was about four times greater for strain cycling than for thermal cycling. The strain hardening characteristics and the stress level produced in the specimen by the two different testing methods differ. Type 347 stainless was used for the tests.

The relationship between the number of strain cycles to failure and the plastic strain change occurring during each half cycle can be used to predict the resistance of structural shapes to thermal stress fatigue. When calculating resistance to failure at locations involving strain concentrations, the strain concentration factors must be included. The calculations in general predict the number of cycles until a crack is formed. Actual complete failure of the structural part might occur only after thousands of additional strain cycles.

G. A. Kemney

Education . . .

(Starts on p. 110)

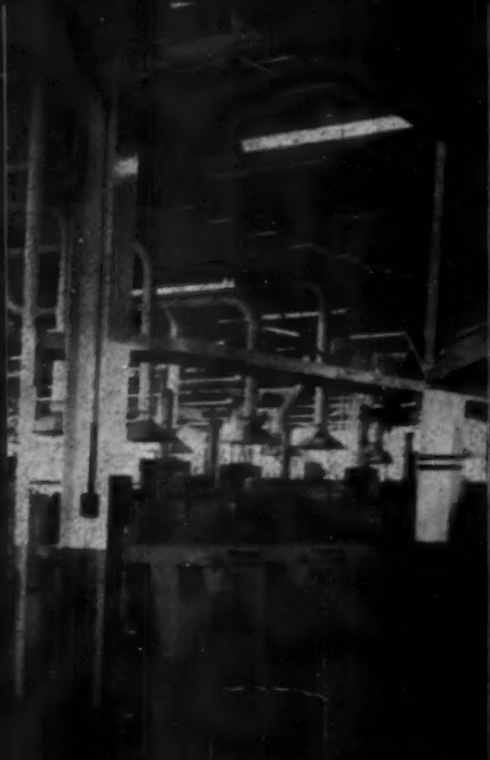
for research and would make top-notch operating men. Research, however, is the glamor girl, and very often in spite of the counseling professor, the temptation to accept a research position is too great. It must also be pointed out that the initial salaries for research are usually somewhat greater than for the operating positions. To the large number of undergraduates who are married and have families, the cumulative effect of greater salary and greater prestige makes very few graduates available for operating positions.

This nation is short of engineers, and faces an increasing shortage of all engineers. There has been a general deterioration in our public school systems in the old and revered (to the older ones of us at least) "three R's". The average matriculate is deficient in arithmetic and algebra, often is unable to read intelligently and is unable to express himself clearly either orally or in writing. However, he is socially well adjusted and, thereby, becomes a better citizen – at least according to the definition of citizenship of the professional educator. (Some of us might debate this definition, but as yet few have. Better social adjustment is incompatible with scholarship. The scholar is *a priori* maladjusted. The socially well-adjusted child is the one who will achieve happiness in mediocrity.)

Engineering education is not easy. The requirements for graduation are generally greater, the homework more arduous. How much easier to take a general course and avoid the horrors of chemistry, physics, and calculus!

A major problem is the shortage of science teachers in the secondary schools. The statistics presented in the 1954 annual report of the National Science Foundation are very discouraging. The number of high-school students taking science courses is alarmingly small. This may be due to inadequacy of instruction, apathy in professional education, or both – all greatly diminish the supply of students prepared for instruction in science and engineering on entrance to college.

(Continued on p. 190)



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Tool and Die Hardening Department at IBM consists of three Ipsen 100 lb./hr. units. These versatile units offer elevated temperature operation combined with complete heating, quenching or cooling under controlled atmosphere.

Complete process control was another IBM "must". This control panel is typical of the advanced automation inherent in heat treating the "Ipsenway".

Education . . .

These are problems affecting all science and *all* engineering and, to a degree, many other branches of learning. Competition for capable students is very keen. To attract the students a direct selling job must be done. At career days and college career carnivals which are held in high schools, engineering is seldom well represented and metallurgy is usually conspicuous by its absence. At most universities there are far more scholarships designated for business or marketing than for engineering. Right from the start it would appear that metallurgy has nothing to sell. Again the lack of professional consciousness!

Curricula such as proposed by Professor Schuhmann are an attempt to remedy this situation. Progress will be slow, and Professor Schuhmann's curriculum is but a step along the way to the day when the metallurgical engineer can hold up his head at the sight of a steel mill (or brass or aluminum) with continuous operation from ore to finished product and say, "For that I am responsible!" Only then shall we attract the brightest, the most ingenious of our young people to this great profession of which we are proud to be a part.

Super-Refractories . . .

(Starts on p. 123)

a protective layer against high-temperature oxidation. A satisfactory single, double or triple protective coating for alloyed molybdenum is of prime importance.

Finally – and perhaps related with some of the above suggestions – is the need for more knowledge about the influence of trace elements. Small quantities of oxides have long been known to improve the creep strength and rupture strength (and frequently to damage toughness and resistance to thermal shock). Cannot something be found with a little of all the virtues and only a few of the minor vices? We have seen what a fraction of one percent of zirconium does to the rupture strength of molybdenum. Perhaps impurity elements in a few parts per million are responsible for large

(Continued on p. 192)

Super-Refractories . . .

behavior differences of supposedly identical materials in powder form.

A *fifth avenue* for advance is, then, the preparation of raw materials of utmost purity and their fabrication with the minimum of contamination.

Much work has been done in the last decade. Perhaps the principal achievement has been to separate a few good prospects from a hundred candidates. Let us now concentrate on these foremost examples of refractory materials, do some intensive work aimed at the designers, builders and maintenance crews, and put the materials into production and use.

Metal Finishing . . .

(Starts on p. 113)

establishment will benefit. Continuous processes for plating steel strip or wire with aluminum or titanium, using fused salt baths, are probably in the offing.

Now that various instruments for measuring coating thickness are available, specifications will be used by the whole manufacturing and consuming industry – particularly for silver and other plating where the cost of the precious metal is such an important factor. The plating industry right now needs to adopt a minimum quality standard for its products to regain the confidence of the consumer and to compete with stainless steel and plastics. The search for accelerated corrosion tests for plated coatings, simulating atmospheric exposure, will go on and on without finding a satisfactory solution. The main basis for judging quality will be thickness and porosity of plate.

Other methods of applying metal coatings, such as flame spraying, gas plating, carbonyl and hydrogen reduction, peen-plating and vacuum deposition will be improved, but will not be largely used because it is so difficult to apply them to a wide variety of objects with satisfactory adherence and uniform thickness. Electrophoretic methods of depositing metals and cermets are to be expected, but since they require subsequent treatments their

(Continued on p. 194)

Metal Finishing . . .

use will be restricted to special applications.

Fundamental research in metal finishing has been hampered not only by lack of interest on the part of the orthodox metal-finishing industry, but also by a shortage of facilities, trained people, and electrochemistry courses in the universities. With the great growth of the metal-finishing field, stimulated by the needs of technology, instruction in electrochemistry will be revived in the universities and more basic research will be done.

Effect of Pouring Variables on Ingot Structure*

Ingots of nickel-chromium case hardening steels will have transverse cracks occasionally if poured at too high a temperature. This investigation was made to determine how structure and segregation in such stubs are influenced by temperature and pouring rate. To eliminate variations in steel composition and maintain temperature as the major variable, a 5-ton melt was tapped in two halves with a temperature difference of 72° F. between them. Additions of ferrous sulphide were made during tapping to obtain uniformly high sulphur contents (0.04%).

Two 1-ton (2200-lb.) ingots were obtained from each half-heat, and different nozzle sizes were used to include the effect of pouring speed. Thus, a total of four ingots was obtained of essentially the same composition and representing four conditions of treatment:

1. 2800° F. teeming temperature; 1-in. nozzle; 70 sec. to fill.
2. 2800° F. teeming temperature; 1⅞-in. nozzle; 30 sec. to fill.
3. 2870° F. teeming temperature; 1-in. nozzle; 69 sec. to fill.
4. 2870° F. teeming temperature; 1⅞-in. nozzle; 30 sec. to fill.

(Continued on p. 196)

*Digest of "Effect of Temperature and Pouring Speed on Ingot Structure", by Ingots Committee, British Iron and Steel Research Association, *Journal of the Iron and Steel Institute*, Vol. 179, February 1955, p. 120-123.

Ingot Structure . . .

Examination of ingots after stripping showed distinct differences in surface condition; Ingot No. 1 had a slaggy surface free of cracks, Ingots 2 and 3 were comparable with normal shop practice and Ingot 4 had numerous transverse cracks.

They were sectioned longitudinally and sulphur printed, macroetched and photographed, and drilled for analysis. All ingots were found to be equally sound and no significant differences were shown by either sulphur prints or analyses. Mechanical properties, obtained on 2-in. square billets rolled from spare portions of each of the half-heats, showed no marked differences.

Macro-etching of the sectioned ingots with a cold 10% aqueous ammonium persulphate etch developed an unusual crystalline structure. It consisted of three columnar zones with only a very small central core of free crystals. From the surface inward, the zones appeared to be a thin shell of fine crystals at right angles to the ingot skin, a very coarse crystalline zone of considerably greater depth than the first and a zone of narrow columnar crystals normal to the ingot surface. A difference in the length of the columnar crystals was the only distinguishing feature between the "hot" and "cold" cast ingots.

Further investigation of this structure was made on transverse slices 1 in. thick, two each being taken from the top, center and bottom portions of Ingots 1 and 4 (cold metal slowly poured and hot metal rapidly poured).

The lower slice from each pair was normalized at 1740° F. and its top surface etched; the lower surfaces of the top slices were also etched, but in the as-cast condition. Various etches were used and structures produced were characterisic for these. Slices were later fractured at the centerline and compared.

It is theorized that the structure revealed by the ammonium persulphate etch is the result of the peritectic transformation in the particular steel under study, since it cannot be accepted as representing the original as-cast structure. Further work is being carried out on the occurrence of this change and resultant structures.

A. C. Coulsen

Tool Steel Topics

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation

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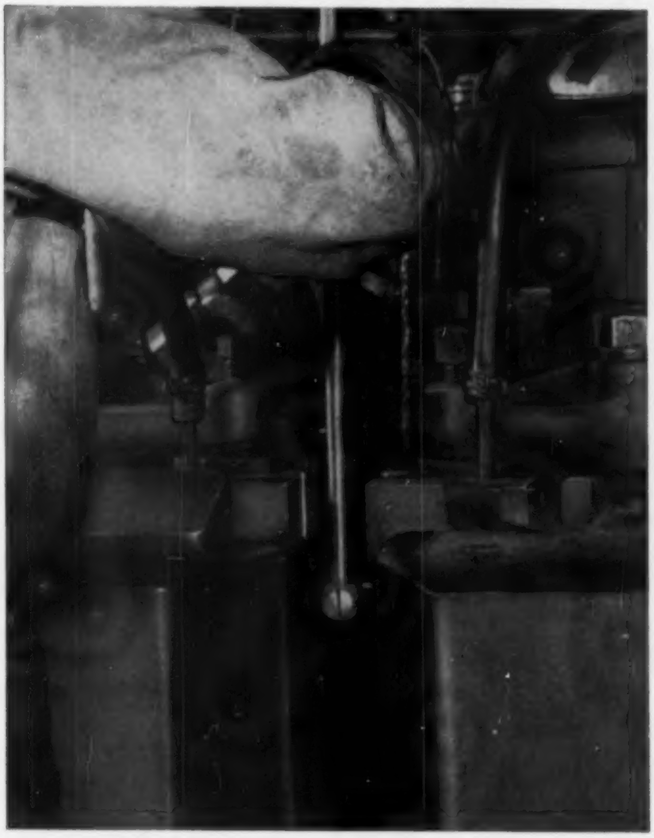

Forging Die of Cr-Mo-W Produces 2000 Steering Links Daily

This is the business end of a hot forging die, used in a West Coast plant to produce socket forgings for automobile steering-linkage assemblies. A typical steering link is shown after the first blow in the multiple-station die, made of Bethlehem Cr-Mo-W (chrome-moly-tungsten) tool steel.

The Cr-Mo-W die, hardened to Rockwell C 52-56, shapes hot-rolled 23/32-in. rounds of 1030 steel at the rate of 300 pieces per hour, producing approximately 30,000 pieces before reworking is required. It is then machined and re-treated, resulting in long service life.

Bethlehem Cr-Mo-W is a general-purpose hot-work tool steel, with a 5 pct chromium content, plus moly and tungsten. It is ideal for jobs involving shock or radical changes of temperature. It hardens in air for exceptional resistance to distortion during heat-treatment. It has good red-hardness, which provides resistance to heat-checking. Cr-Mo-W also machines easily, as it can be annealed to 217 Brinell.

Cr-Mo-W is used extensively for applications such as trimmer dies, die-casting dies, hot-shear blades, and various types of punches. Why not look into this fine tool steel? Your nearest Bethlehem tool-steel distributor will be pleased to furnish full information. He can offer good delivery, too.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

How to Machine Heat-Treated Tools

Machining hot-work tools and plastic and die-casting molds directly from bar stock heat-treated to Rockwell C 30-45 presents many a problem.

Carbide tools are preferred, though they require careful handling. Due to the high hardness of the metal being cut, much heat is generated during machining, causing the carbide tools to wear rapidly. To cut pre-hardened tool steels in turning, boring, planing and milling operations, use speeds of from 60 to 120 surface ft per min.

High-speed steels can be used in such operations with cutting speeds of 15-25 surface ft per min, though tool life will be short. Conventional drills of high-speed steel are satisfactory if the cutting speed is slowed. Conventional tapping of threads rarely succeeds, single-point lathe tools being used instead.

The advantages of pre-hardened tool-steel stock — the elimination of heat-treatment on the machined tool, and the exact control maintained over tool dimensions — must be weighed against the difficulties encountered in machining, which have frequently been considered insurmountable.

Omega Chisels Bite Deep, Stay Sharp

Because Bethlehem Omega has a normal working hardness at the cutting edge of Rockwell C 58-60, chisels made of this fine tool steel hold their sharp edge. Omega combines shock-resistance with hardness and ductility. It is easy to forge, redress, and heat-treat, and can be hardened in oil or water.

Effect of Stress Concentration on Rupture Strength*

Four factors determine the rupture strength of notched specimens of high-temperature alloys in creep. These are test temperature, time at temperature, notch geometry, and alloy composition. The effect of time and temperature on, for example, the reduction of area at fracture is quite similar for notched and unnotched specimens of high-temperature alloys. If the reduction of area at fracture is plotted versus time for various test temperatures, the curves for both notched and unnotched specimens look like inverted aging curves.

A minimum ductility is observed at each temperature and the time at which it occurs decreases with increasing temperature. The value of ductility at the minimum increases with increasing temperature. Structural changes in the alloy occur that render it brittle regardless of whether there is a notch or not.

The effect of a notch is clearly shown by plotting the notch strength ratio, which is the ratio between the rupture strength of unnotched and notched specimens, against temperature or time. This effect also must be due to structural changes which take place in the alloy during testing, for a maximum notch sensitivity is reached after a certain "aging" time. There is often only a little notch effect at high temperatures at which the alloy quickly "over-ages", or at low temperatures where "aging" generally cannot take place.

It would be very desirable from a practical point of view to predict the behavior of a notched alloy from tests on unnotched specimens since notched specimens are certainly more costly. Unfortunately no precise relationship has yet been found between the properties of notched and unnotched samples in creep. It can be concluded that notch brittleness is highly unlikely for an alloy if its reduction in area at fracture is larger than 40% for an unnotched

(Continued on p. 200)

*Digest of "The Effects of Stress Concentrations on the Rupture Strength of Materials Subjected to Creep Loading", by G. Sachs, D. P. Newman and W. F. Brown, *Zeitschrift für Metallkunde*, Vol. 44, June 1953, p. 233-239.

NATCO ENGINEERS

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WITH

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SEVERELY COLD-WORKED, FURNACE-TREATED STEEL BARS

The Lead Screw Tapper Spindles of this Natco Three-way Holetapper required machining operations hard to combine without serious distortion.

The front end of each spindle had to be machined as a taper socket for collet application. When the driving keyway and the tool knockout elongated-splined-holes were machined, distortion caused out-of-round taper holes which would not receive the collet correctly.

The rear end of each spindle had to be machined as a driving spline shaft which slides under load. Since the diameter of the spline is relatively small in proportion to the shaft length, any attempt to heat treat caused distortion hard to correct by straightening.

And at the center of each spindle, an accurate lead screw had to be machined by a thread grinding operation. It was found that the finish was much more easily obtained when STRESSPROOF was used.

STRESSPROOF eliminated both the problem of the out-of-round taper holes on the front of each spindle . . and the distortion of the driving-spline-shaft.

STRESSPROOF makes a better part at a lower cost.

National Automatic Tool Co. has for many years used STRESSPROOF in the manufacture of important operating parts for this Three-way Holetapper, as well as for other Natco high-speed machine tools.

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Rupture Strength . . .

specimen and if this value increases with time. On the ther hand, notch brittleness is likely to be encountered if the reduction of area at fracture is less than 10% for an unnotched specimen and if this value is found to decrease during long times at test. No predictions can be made from ordinary creep tests if the reduction of area of unnotched specimens lies between 10 and 40%. When notch brittleness is encountered, the rupture strength is generally low.

The effect of notch geometry on the creep-rupture strength has been studied on a few alloys only. It seems that this effect is the same in creep as it is in ordinary tensile tests at room temperature. The notch strength ratio is always greater than one for ductile specimens with sharp notches. For less ductile, notch-sensitive specimens the notch strength ratio first increases, reaches a maximum, and then decreases to values of less than one.

The effect of composition on notch sensitivity has been studied in several alloys. Low-alloy chromium-nickel steels behave in about the same way as high-alloy ferritic stainless steels. In both, a minimum of ductility is found. The time for reaching this minimum decreases with testing temperature. The amount of the notch sensitivity and the critical temperature range depend on the particular alloy. Too few data on austenitic steels are available to indicate whether austenitic steels behave differently from low-alloy ferritic steels. Nickel and cobalt-base alloys have hardly been studied. It is known only that Inconel "X" is extremely notch sensitive between 1290 and 1380° F.

There is a pronounced effect of structure on the notch sensitivity of an alloy. Notch brittleness is observed for some alloys when the heat treatment is changed slightly. For example, a low-alloy chromium-nickel-molybdenum alloy is notch insensitive after spheroidizing.

In addition to structural changes, cold work can influence notch brittleness in creep. If bars of certain austenitic steels are twisted at room temperature by increasing amounts prior to testing, they become more and more notch-sensitive.

(Continued on p. 202)

Rupture Strength . . .

It seems to this reviewer that it would be very desirable to use a more fundamental approach in studying the phenomenon of notch brittleness. Evidently, certain precipitated phases with proper size, shape and distribution of particles cause notch brittleness, but it seems no effort has been made to study this phenomenon. Rather than making and testing new series of alloys, the effect of structure on notch sensitivity of one existing high-temperature alloy should be established.

A. W. Cochardt

Changes in Porosity When Sintering Copper Compacts*

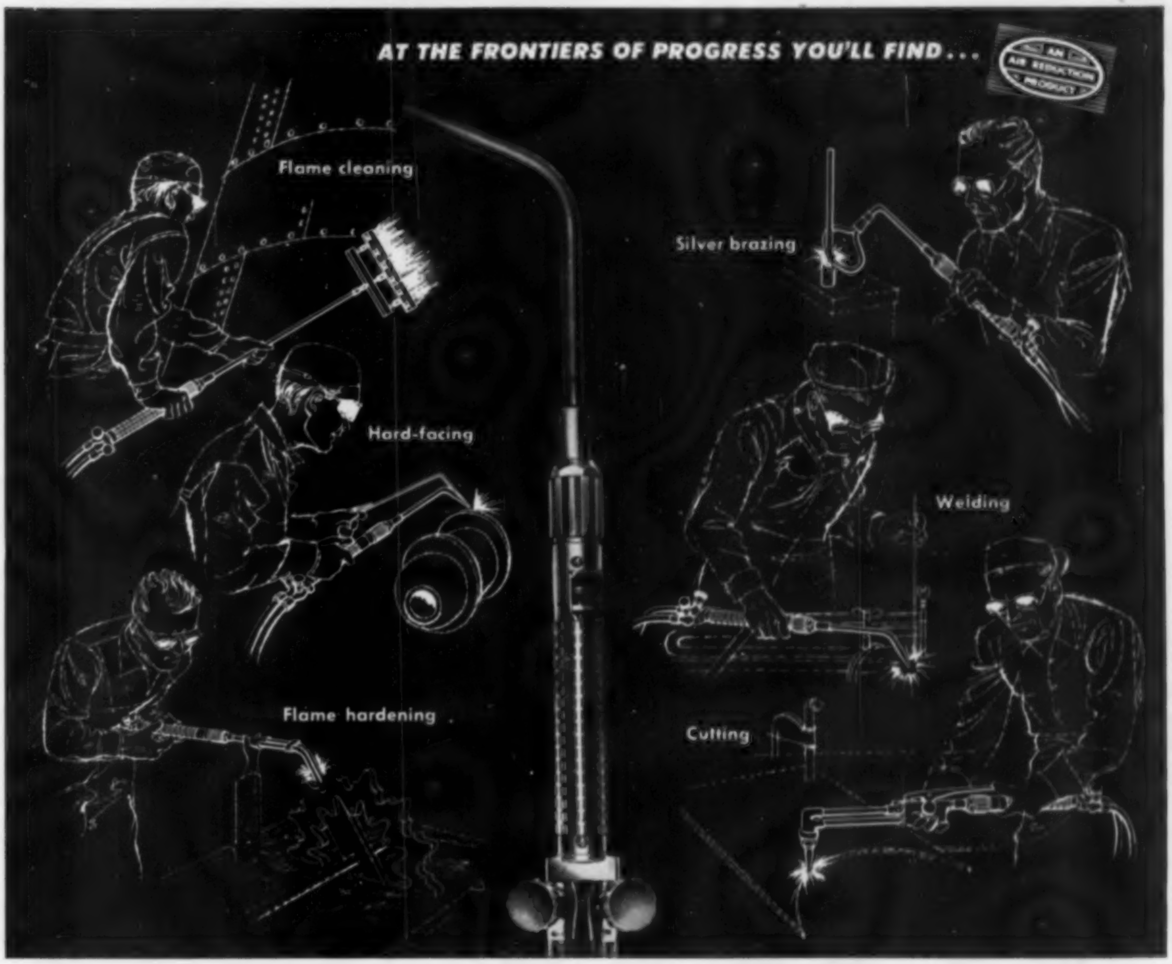
The paper under review attempts to explain the observed porosity and permeability of sintered porous copper with some theories of the sintered process. At the very outset comes the problem of measuring both interconnected and closed porosity (the latter being the difference between total and interconnected porosities). Another parameter introduced in the discussion is the "specific surface" of a porous metal, which – lacking simple and reliable methods for measurement – is related to porosity and permeability.

The experimental work was done on loose-sintered and on compacted copper powder of particle size either less than 300 mesh or between 300 and 200 mesh. Compacting pressures ranged from 5 to 30 tons per sq. in. Sintering temperature was 1830° F.; times ranged from 15 min. to 100 hr. Permeability was related to interconnected porosity in specimens prepared with a given powder, loose-sintered for various lengths of time. From this relation it was concluded that the specific surface does not remain constant during sintering, but decerases steadily, except at the end when the interconnecting porosity becomes very small.

Interesting variations were found

(Continued on p. 204)

*Digest of "Porosity and Permeability Changes During the Sintering of Copper Powder," by G. Arthur, *Journal* of the Institute of Metals, Vol. 83, 1955, p. 329.



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between interconnected, closed, and total porosity. Interconnected porosity decreases steadily with increasing total porosity, whereas the closed porosity remains about constant. Both interconnected and open porosity, when plotted against total porosity, were independent of compacting pressure. The author concluded that closed pores are being formed from open pores and are being removed at approximately the same rate, so that the relative volume occupied by closed pores is nearly constant. Reduction in volume of open pores is therefore the main reason for the increase in density during sintering.

Correlating these experimental results with the fundamental theories of sintering, the author concludes:

1. Since the specific surface (computed) increases with compacting pressure, cold compacting increases the driving force controlling the rate of sintering.

2. With the exception of the initial sintering period, the type of powder (angular or spherical in shape) has little effect on specific surface.

3. As sintering proceeds isothermally, the connected porosity is always larger than the closed porosity. The proportion of open to closed porosity is not influenced by compacting within the limits of 5 to 30 tons per sq. in.

4. The experimental results are not in agreement with current theories of sintering.

The theory based on the model of Clark and White predicts that the porosity would be completely closed when the total porosity reaches 33%, which is at variance with the experimental facts. The density-versus-time relationship of MacKenzie and Shuttleworth does not agree with the measurements for the early stages of sintering. The diffusion theory of Rhines, Birchenall and Hughes predicts that pores which are near the surface should close faster than those inside the specimen, yet this was not observed.

Although the author does not explain very clearly what his own ideas are about an improved theory of sintering, he suggests that surface diffusion is probably the most important mechanism controlling the rate of sintering. Pol Duwez

Corrosion Resistance of High-Manganese Stainless Steel*

CARBON, nitrogen, nickel, manganese, and copper promote the retention of austenite at room temperature in stainless steels. Of these elements nickel is the most widely used, but some steel producers have been replacing part of the nickel with manganese in the austenitic stainless steels. This paper compares the properties of an 18% Cr, 10% Mn, 2% Ni stainless alloy stabilized with titanium with those of a Ti-stabilized 18-8 Cr-Ni steel and a 17% Cr ferritic steel. The material used for testing was annealed sheet 0.036 to 0.040 in. thick.

The yield strength of the chromium-manganese steel was about 28,000 psi. greater, and the tensile strength about 6000 psi. greater than that of the chromium-nickel steel. The greatest difference was in the ductility. The elongation of the chromium-nickel steel was about 55%, and the elongation of the chromium-manganese steel was about 30%. In deep drawing the chromium-manganese into a cup, the blank holding pressure had to be reduced from 240 psi., used in drawing chromium-nickel steel, to 40 psi. Very bad crimping occurred in the cup which was drawn from the chromium-manganese steel.

The structure of the chromium-manganese steel consisted of approximately 50% ferrite and 50% austenite with inclusions of titanium carbo-nitrides. There was no change in structure on reheating at 1560° F. for various times up to 1000 hr. Sigma phase precipitated at the ferrite grain boundaries when the material was reheated at 1200° F., and the amount increased with time and spread across the ferrite grains. Ductility rapidly decreased, hardness increased, the amount of ferromagnetism decreased, and the resistance to corrosion in nitric acid decreased with increasing sigma formation.

The three types of stainless steel were tested in boiling 65% nitric

(Continued on p. 208)

*Digest of "The Properties of a High-Manganese Austenitic Stainless Steel", by G. N. Flint and L. H. Loft, *Metallurgia*, Vol. 51, March 1955, p. 125 to 129.

High-Mn Stainless . . .

acid, boiling phosphoric acid solutions, in a circular-path corrosion-test apparatus in aerated solutions of 50% acetic acid, 25% citric acid, 50% phosphoric acid, and saturated ammonium alum at temperatures of 85 and 120° F. The relative resistance of the steels to attack by stagnant solutions of sulphurous acid and inorganic chlorides was also determined. The corrosion resistance of the chromium-manganese steel is similar to the 17% chromium steel, but less than that of the chromium-nickel steel, except in sulphurous acid where the corrosion resistance of the chromium-manganese steel is better than that of the 17% chromium steel. The chromium-manganese steel has less resistance to crevice attack in an aqueous solution of 4% sodium chloride and 1% lactic acid than either the 17% chromium steel or the chromium-nickel steel.

After an 18-month exposure to an industrial atmosphere, samples of the three types of stainless steel were examined by microscopic methods. The chromium-manganese steel showed the poorest resistance to atmospheric corrosion, and the chromium-nickel was the best. Although the chromium-manganese steel had more pits per unit area than the 17% chromium steel, the depth of pitting was greater in the 17% Cr steel.

The steels were tested for relative resistance to pitting attack in a solution of 0.2% ammonium chloride with varying additions of ferric ammonium sulphate up to 10%. The tests were conducted in a circular-path machine for four days at 85° F. The chromium-nickel steel is much superior in resistance to pitting than the 17% chromium steel, which is slightly better than the chromium-manganese steel.

Samples of the chromium-manganese steel were gas welded using standard filler rods of 18-8 Cb-stabilized steel. Microscopic examination did not reveal any significant intergranular attack of the weld or heat-affected zone, although there was excessive grain growth in the vicinity of the welds. The structure of the coarse-grained zone was completely austenitic. There was a progressive diminishing of the amount of titanium carbo-nitrides present on

(Continued on p. 210)

XI

This is the eleventh of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

How Alloy Steels Are Affected by Molybdenum

There is nothing hit-or-miss about the making of alloy steels. Each element in a given analysis is chosen for its ability to do a special job—or to complement the abilities of other elements. Previously in this series of discussions we have briefly outlined the functions of nickel and chromium. This leads us naturally to molybdenum, a highly reliable performer in numerous types of analyses.

Because of its many desirable properties, molybdenum is one of the most respected of all the alloying agents. It is often used in conjunction with chromium, manganese, nickel, cobalt, tungsten, vanadium, or various combinations of these elements.

Molybdenum promotes hardenability in steel, and is useful where close hardenability-control is essential. It increases depth-hardness and widens the range of effective heat-treating temperatures. Moreover, it has a strong tendency to form stable carbides that hamper grain-growth prior to quenching, thus making the steel fine-grained and unusually tough at the various hardness levels.

Another point in favor of molybdenum is its ability to increase the tensile and creep strengths of alloy steels at high temperatures. Still another is its talent for enhancing corrosion-resistance in high-chromium and chromium-nickel steels.

Among the familiar products that frequently contain molybdenum are high-speed cutting tools, forged crankshafts and propeller shafts, turbine rotors, high-pressure boiler plate, high-pressure cylinders, permanent magnets, and armor-piercing projectiles. This is by no means intended as a complete list, but rather as a few typical examples.

If you would like more information about the properties and applications of molybdenum, Bethlehem metallurgists will be glad to help you. Our staff technicians have devoted years of research to the subject, and working with molybdenum is part of their job. As a matter of fact, they are specialists in all types of alloying elements, and all types of alloy steels. When they can be of assistance to you, please feel free to call them.

And call on Bethlehem, too, when in the market for AISI standard steels, special-analysis steels, or carbon grades. Your inquiries will be welcomed, and we can assure you of prompt service.

BETHLEHEM STEEL COMPANY
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On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

High-Mn Stainless . . .

going from the unaffected sheet material to the weld metal, indicating that carbon had been taken into solution. In the heat-affected zone there was a precipitation, probably chromium carbides, at the grain boundaries and within the grains.

The results show that the chromium-manganese steel has less ductility than the chromium-nickel steel which is probably due to the mixed austenite-ferrite structure. The ductility could probably be increased by increasing the manganese or nickel content to produce a completely austenitic structure. Although the chromium-manganese steel does not have the same high corrosion resistance as the chromium-nickel steel, it is still suitable for applications in which the requirement calls for an austenitic steel having corrosion resistance of approximately the same order as that of the straight chromium steels.

H. E. McCune

Pressure Welding of Tubular Sections*

HERETOFORE aircraft undercarriage components had been made in England from forging ingots weighing as much as 2 tons. A review was made of American fabricating practices of similar structural components and showed that the oxy-acetylene pressure welding process has considerable merit (see L. Fine, C. H. Maak and A. R. Ozanich, *Metal Progress*, Vol. 49, 1946, p. 350-355, 530-536). As a result a development program was set up in the plant of Rotol Ltd. under contract by the British Ministry of Supply. The program consisted of three stages: the development of a simple experimental set-up, the construction of a small prototype machine and design and construction of a production machine suitable for the various sizes and face areas of undercarriage components.

The final machine looks like a

(Continued on p. 212)

*Digest of "Oxy-Acetylene Pressure Welding on Aircraft Undercarriage Components", by D. C. Brown and J. J. Wilson, *British Welding Journal*, Vol. 2, April 1955, p. 160.

Removing heat from an Inconel retort at the Bullard Company plant. This is one of six pit type furnaces used to carburize heavy gears used in Bullard Horizontal Boring, Milling and Drilling Machines; Bullard Cut Master vertical Turret Lathes and Bullard Mult-Au-Matic vertical Chucking Machines.

Inconel triples life of pit carburizing retorts at Bullard plant

Averages 12 months' service at 1700°F ...then 6 more when repaired

Is your heat treating equipment lasting as long as it should?

If not, maybe you should try Inconel* nickel-chromium alloy.

Take what happened at the Bullard Company. Retorts up to 84" deep, used to carburize machine tool parts at 1700°F, were failing within six months.

Then Rolock, Inc. came up with a suggestion ... wrought Inconel. This change in alloys immediately boosted retort life to 12 months. What's more, with this ni-cr alloy, these pots are being repaired by welding, to add an additional 6 months.

*Reg. Trademark

It often works out that way with Inconel. Not only do you get longer life to start with . . . but you also have a high degree of repair ability besides.

There are sound reasons for this. The Inconel pots resist damage by oxidation, carburization and other forms of high temperature attack. This alloy retains its useful properties to 2100° F and over in some applications. It withstands thermal shock. It retains forming and welding properties despite sustained hot service.

So maybe Inconel nickel-chromium alloy is the metal you should try next. Check with your fabricator ... or write

The International Nickel Co., Inc.
67 Wall Street New York 5, N. Y.

Inconel retort has two lives. On the average, new wrought Inconel retorts fabricated by Rolock, Inc. give Bullard twelve months service. When failure appears imminent, Bullard simply has Rolock weld on a new Inconel bottom to add six or more months extra service.

Inconel... *for long life at high temperatures* INCO Nickel Alloys

Pressure Welding . . .

horizontal hydraulic press with a capacity of 50 tons. Its over-all dimensions are 18 ft. long, 6 ft. wide and 4 ft. high and it is capable of welding joints in high-tensile steel sections with a maximum area of 25 sq. in. Components up to a diameter of 15 in. and a combined length of 10 ft. can be accommodated.

The flame ring is of the water-cooled, removable, inserted-jet type for jets ⅜ to 1 in. long to allow for variations in the diameter of the component to be welded. For easy removal of the weldments the flame ring is made of two halves hinged at their lower ends. Microswitches are provided to extinguish the flame after a previously determined linear movement of the sliding head.

The controls are incorporated in a panel with the button controlling the cooling water supply to the flame ring acting as master control. Six pairs of buttons control in sequence cooling water, hydraulic pump motor, flame-ring oscillating motor, acetylene gas valve, electrically operated flame-ring igniter and oxygen gas valve.

Satisfactory heating rates were obtained with a gas flow between 375 and 450 cu. ft. per hr. The triple pressure cycle used consisted of an initial (cold) pressure of 5500 psi., a holding pressure during heating of 680 psi. and an upsetting pressure of 5500 psi. applied at about 2000° F. The tubular alloy steel sections tested were 9.75 in O.D., 8.45 in. I.D., 5 in. long.

The tubing with joint faces ground and polished was upset at 2010° F. by an amount sufficent to double the area at the interface. The weld strength was about the same as that of the base metal (115,000 psi.) but the elongation was reduced from about 22 to about 14%.

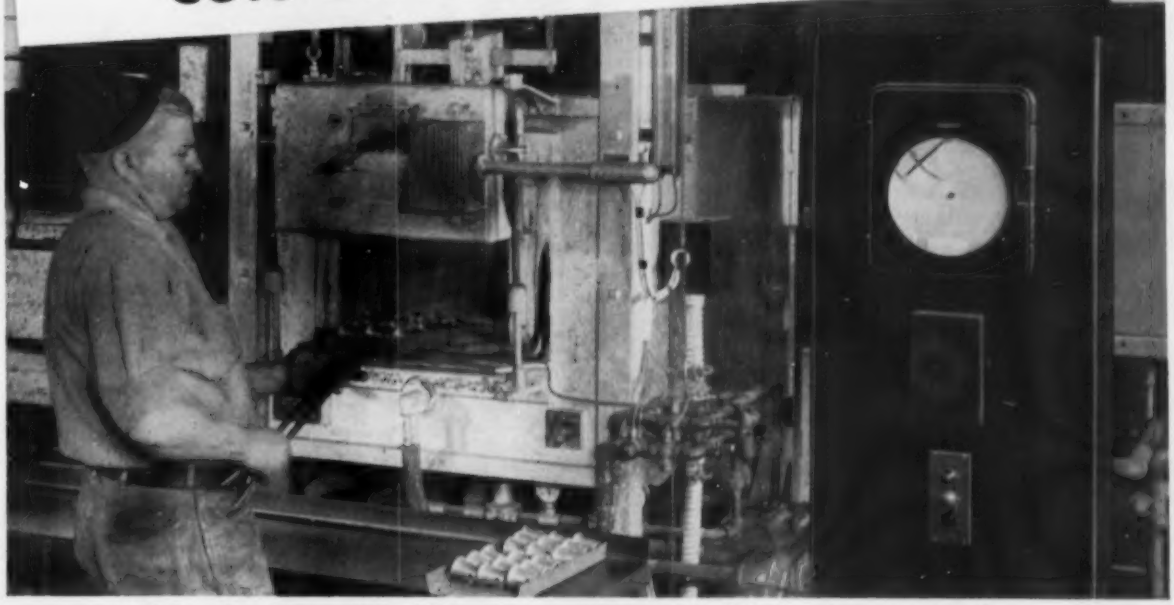
The jet-to-work distance was found to be extremely critical. Best results were obtained with a distance of 1.2±0.015 in. A variation of as little as 1/16 in. increased the necessary welding time and reduced ductility to less than 10%.

An undercarriage was welded and tested to destruction by the Royal Aircraft Establishment. Failure occurred in a part of the undercarriage away from any weld.

H. Thielsch

R. I. Heat Treating Co.

CUTS STRAIGHTENING COSTS 50%!



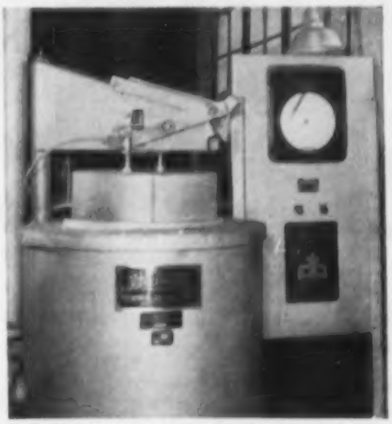
Foxboro Control *automatically* holds working temperatures within ¼% of chart range in this Hayes atmosphere furnace at the Rhode Island Heat Treating Company, Providence, R. I. Heat cycles may vary from 10 minutes to 18 hrs. on such precision parts as watch pinions, dial indicator hands, and stamping dies.

. . . with Foxboro Automatic Temperature Control

A wide variety of precision parts ranging from tiny watch pinions to 700 lb. stamping dies is handled by the Rhode Island Heat Treating Company. To assure maximum shop output, the company is constantly striving for greater productivity and economy in every operation.

Recently this progressive jobbing company stepped up the efficiency of hardening and tempering operations by replacing manual temperature control of two furnaces with Foxboro Dynalog Temperature Controllers. Besides the outstanding savings in operators' time thus effected, the greatly increased accuracy of Foxboro Control reduced work distortion . . . cut straightening costs 50%!

Foxboro Temperature Control Systems are constantly increasing the efficiency of all types of furnaces throughout the industry. Put new accuracy and economy in *your* heat treating operations. *Write for illustrated Bulletin 427.* The Foxboro Company, 529 Neponset Ave., Foxboro, Mass., U.S.A.



Difficult hardness specs are regularly met using this Eclipse tempering furnace equipped with Foxboro Automatic Temperature Control. Tolerances of 57-59; 58-60; 59-61 Rockwell are easily duplicated day after day.

FOXBORO
REG. U. S. PAT. OFF.

AUTOMATIC TEMPERATURE CONTROL

FACTORIES IN THE UNITED STATES, CANADA, AND ENGLAND

Pros and Cons of Shell Molding Process*

In assessing the shell molding process, it is well to keep in mind that the technique is relatively new and progress is rapid. What may appear as a drawback today may be overcome in a year. However, as the picture looks today from the vantage point of a foundry with four years experience in high-alloy castings, some definite evaluations can be made, useful to both producer and consumer.

For the producer, the shell mold process means cleaner and lighter operations in terms both of materials to be handled and equipment involved. Shell molds are durable, waterproof and can be stored for long times. Mechanization of mold production is not overly expensive. A machine for making shells of reasonably good size and quality at a rate of one a minute costs less than $5000. At the same time, less skill is required to handle these units than for conventional green sand molding machines.

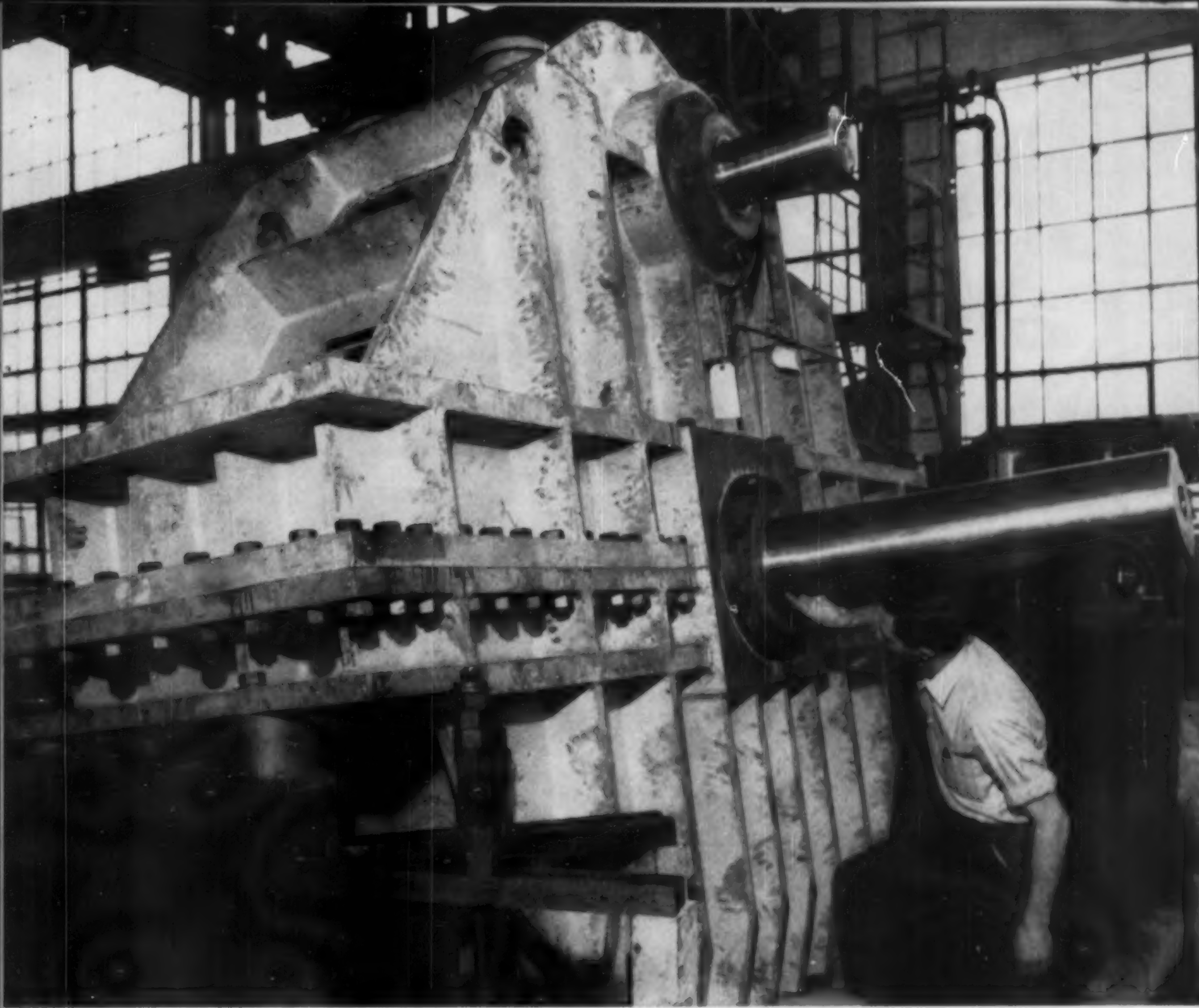
Lower pouring temperatures result in less wear and tear on furnace and ladle linings, less sand wash, slag and hot tears. Smaller risers give better yields and consequently more castings per ton of metal melted.

Ready collapsibility of shell molds permits production of relatively large, intricately shaped castings to precision tolerances. An accompanying factor is accurate location of cores. Tolerances of ±0.002 in., both in core print location and size, are often specified.

On the negative side is the high initial casting cost, particularly on short runs. It is due to a combination of high-cost materials that cannot be re-used (sand and resins), and expensive metal patterns which must be carefully protected from even minute damage. The cost

(Continued on p. 216)

*Digest of "What Does Shell Molding Offer the Producer and User of Castings?" by W. H. Dunn; presented at Western Metal Congress, March 28, 1955.



Shell Molding . . .

makes it imperative that high quality standards be observed and often calls for complete overhauling of inspection procedures.

New gating and risering techniques must be developed for shell-molded castings. Patterns with loose pieces cause considerable trouble, and in addition the number of pattern shops that can supply metal patterns to tolerances of 0.002 in. is, so far, seriously limited.

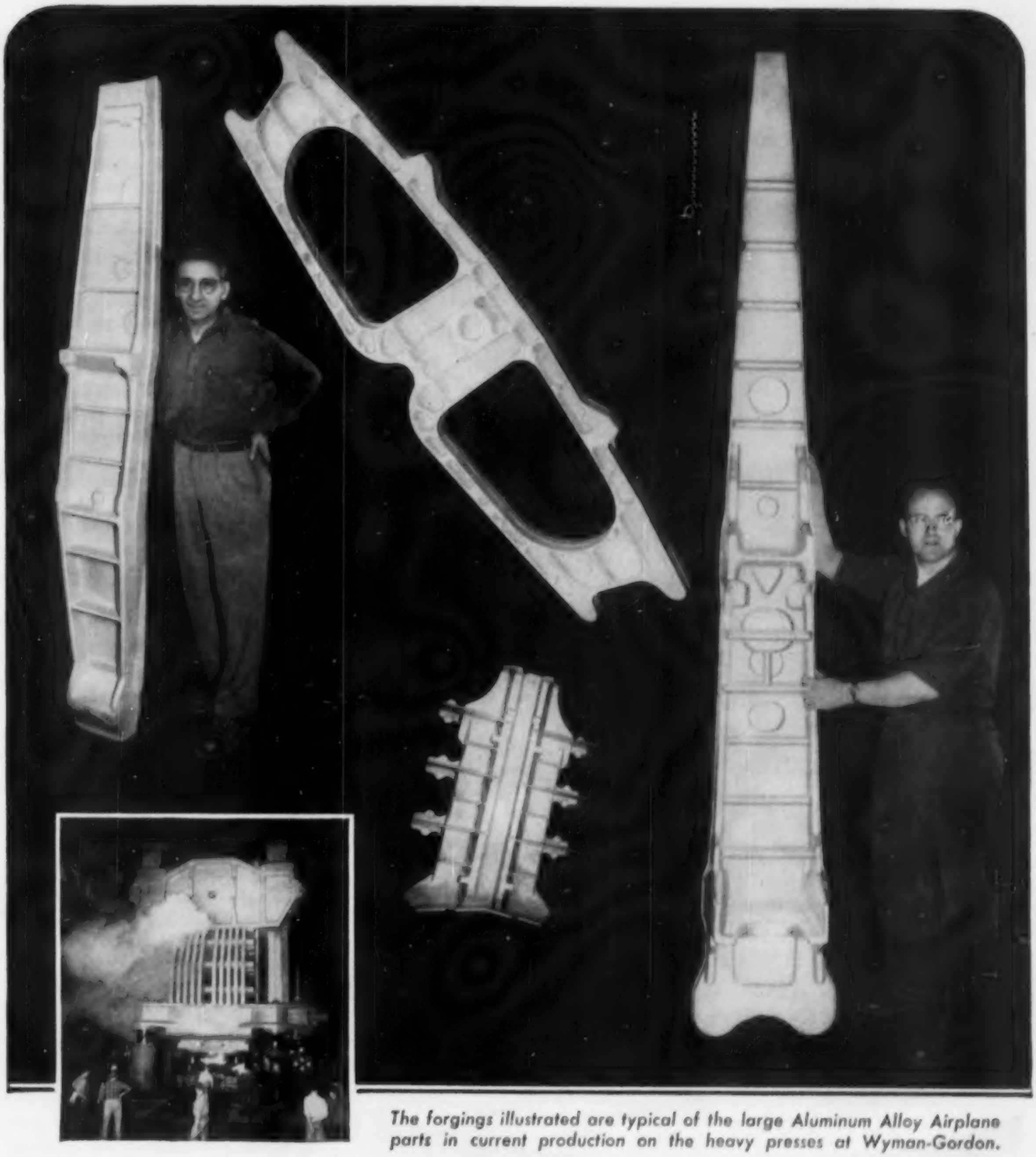
For the user of shell-molded castings, the principal attraction is the close and consistent control of dimensional tolerances. Castings up to 30 in. long have been produced with total variation of less than 0.040 in. As sizes increase, control of tolerances can be even closer. Along with dimensional exactness and good reproducibility is a superior finish with minimum machining requirements and lower over-all cost for the casting as compared to green sand castings.

Grain structure in shell-molded castings is much finer than in identical parts made by other processes. The explanation is that to some extent the shell mold acts as a chill and approaches the effect of a permanent mold.

Thin walls are cast readily. Examples cited from regular production in high-alloy material are castings with 3/16-in. walls, 8 in. wide by 60 in. long, and others with walls 0.060 in. thick on pieces 32 in. long.

Shortcomings, from the viewpoints of users, include the lack of specifications for shell molding, at least for steels and high alloys. This is a matter which could be easily corrected in the near future by cooperative effort. Size limitations constitute another drawback, the largest shell molds thus far made ranging up to 60 in. long and 18 in. wide. Even castings of this size were unheard of two years ago. Currently a molding machine capable of handling patterns up to 48×72 in. is being considered. It will probably be outmoded by demands for larger sizes before it is ready for operation.

(Continued on p. 218)



Shell Molding . . .

Some metals are difficult to cast in shells, the lower carbon steels being one example. Carbon pick-up on the surface has been a problem, just as it is for high-alloy materials.

As mentioned briefly before, high pattern costs present a serious obstacle to the economical production of lots of less than 100. Efforts are being pressed to reduce pattern costs, but as yet they have not been too successful. Time could change that situation.

In summary, shell molding offers advantages in terms of good tolerance control, better finish and lower over-all cost of a machined casting particularly where substantial volume is required (the automotive industry, for example). If the parts are of intricate design and difficult to machine, or if they must have better properties and more consistent quality, then shell molding should be considered.

A. H. ALLEN

Hard Solder for Aluminum*

IMPROVEMENTS are continually being demanded by fabricating engineers and sometimes can be supplied by metallurgists. The hard soldering process for alumnium provides a recent example. The need is evident to anyone who reads in the A.S.M. Metals Handbook, "Since all solders are composed of metals possessing solution potentials different from that of aluminum, corrosion failure of the joints may occur in the presence of an electrolyte. Many salt-type fluxes leave a residue that accelerates corrosion. . . ."

The new process operates between 860 and 1020° F., using a torch for heating. Joints can be made easily and possess satisfactory ductility, strength, and corrosion resistance. In comparison, the conventional "brazing" of aluminum uses aluminum-silicon or aluminum-silicon-copper alloys with suitable fluxes, and temperatures governed by the melting range of the alloys used—

*Digest of **"Hard Soldering Process for Aluminum,"** by W. J. Smelie, *Metal Industry*, April 22, 1955, p. 307-310.

the minimum being 1020 to 1060° F. for an 85-11.5-3.5 Al-Si-Cu brazing alloy. Since the operator must go 75 to 100° F. above the melting point of the filler rod, a minimum temperature of 1110° F. will be reached in aluminum brazing. Pure aluminum melts at 1220 so very little margin exists and skilled operators are required. If the job will stand this temperature, aluminum brazing gives good results, including good corrosion resistance.

In ordinary soldering, operating temperatures are much lower – that is, below 480° F. – since the solders are fusible. Often the pieces are first tinned, which is a nuisance. The resultant joints leave much to be desired in regard to corrosion resistance.

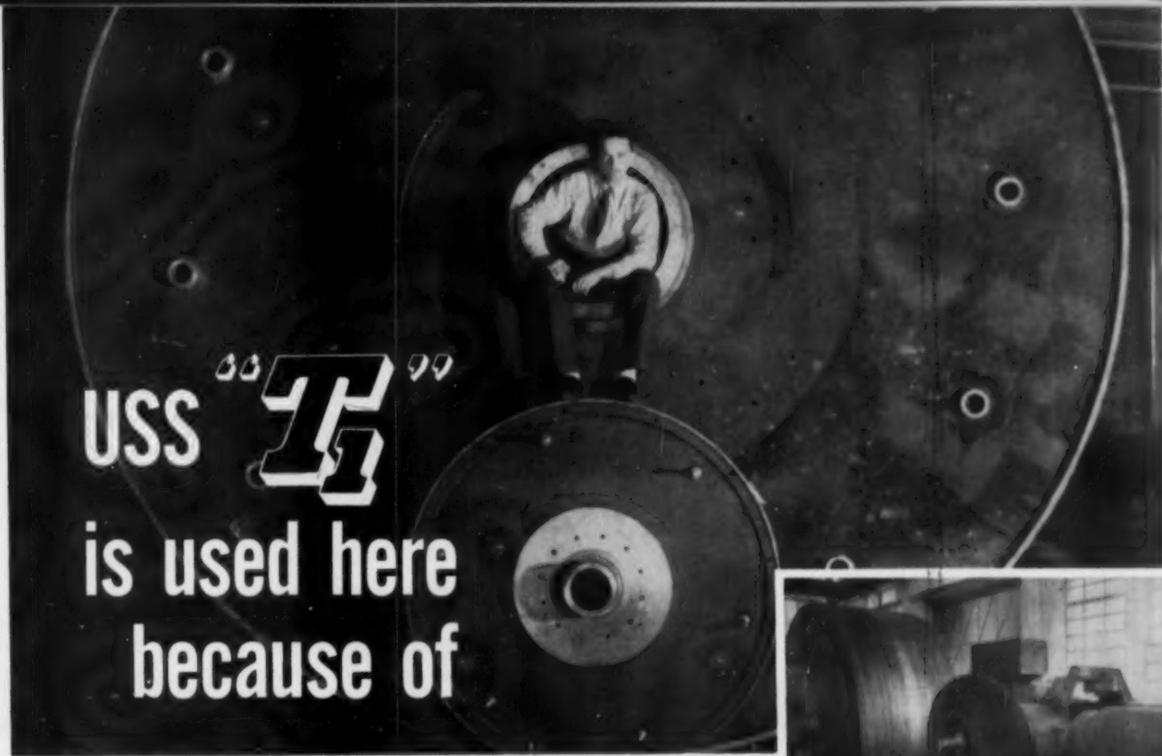
The new "Thesscal" process, so-called, has been approved by authoritative specification bodies in England under specifications D.T.D. 900/4367 and D.T.D. 900/4398. Solders and special fluxes are available for soft aluminum, hard alloys (duralumin), the aluminum casting alloys, aluminum bronze, brasses, copper and steel, but not for magnesium. The physical properties of the two hard soldering alloys are:

	Thesscal A	P 12
Yield	18,500 psi.	41,500 psi.
Tensile	21,000	43,500
Elongation	5%	4%
Conductivity	22.3	32.0

The melting point of the flux is 750° F., about 50° below the solidus of the two alloys. Joints exposed to the corrosive Sheffield atmosphere, using couples of aluminum to aluminum, aluminum to copper, and aluminum to steel, were still quite sound after 18 months. Joint design is discussed. Attention is drawn to the fact that duralumin sheets can be satisfactorily joined, saving weight at no sacrifice of strength, by using thinner sheets of the stronger material. The main benefits are said to be:

1. Less time for joining the pure aluminum.
2. Thin sheets of aluminum can be joined.
3. Weight is saved by replacing aluminum sheet with a thinner, stronger alloy.
4. Aluminum and aluminum alloys can be joined to other metals.
5. Aluminum alloy castings can be repaired.

Harold J. Roast



...its great strength
...its ease of fabrication

'ROUND AND 'ROUND the flywheel goes, at a speed of 300 mph. Suddenly, an aircraft wheel assembly rams against it, with the impact of a loaded airplane. The tire squeals, the brake is applied, and in just 20 seconds the wheel stops. A real rugged test—both for the wheel assembly and for the steel in the flywheel. USS "T-1" Steel passed the test. In fact it is the best steel that could be used for this high speed application.

High speed tire, brake, and wheel testing machines like the one shown here, manufactured by Adamson United Company, Akron, Ohio, a subsidiary of United Engineering and Foundry Co., are used to prove out aircraft landing gear. The gigantic flywheels on these machines simulate the speed and inertia of an actual airplane during landing and take-off.

Until a short time ago, testing machines were built to rotate at peripheral speeds up to 250 mph. But when the aircraft industry spread its wings, faster testing machines were needed. The new machines had to rotate at speeds as high as 300 mph—and stay in one piece. They had to be extremely strong . . . lightweight . . . and easy to fabricate.

That's when USS "T-1" Steel entered the picture.

For flywheels rotating 300 mph, a steel of extremely high tensile strength was needed to withstand the tremendous stresses generated. A steel permitting the greatest strength for the thinnest section was needed. And, above all, the steel had to be capable of developing full 100% weld strength.

USS "T-1" Steel more than met all Adamson United's requirements.

Other steels could have provided the strength and met the weight requirements. None but "T-1" provided these and good weldability too.

UNIQUE PROPERTIES—"T-1" Steel's unique combination of physical properties has solved many similar problems. "T-1" can be welded satisfactorily *without* pre- or post-heating—it can be welded either in the shop or field. Always, it provides great tensile strength (105,000 psi minimum with yield strength of 90,000 psi minimum), phenomenal toughness and excellent abrasion resistance. Write for full particulars. United States Steel, Room 4902, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

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UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS "T1" CONSTRUCTIONAL ALLOY STEEL

UNITED STATES STEEL

Invitation to Entrants . . .

10th Metallographic Exhibit

Entries are invited in the 10th A.S.M. Metallographic Exhibit, to be held at the National Metal Exposition in Philadelphia the week of Oct. 17 through 21, 1955. Entries will be displayed to good advantage and awards will be given for the best micrographs as decided by a committee of judges.

Awards and Other Information

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which, in the opinion of the judges, closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $100, will also be awarded the exhibitor whose work is adjudged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's National headquarters in Cleveland.

All photographs may be retained by the Society for one year and placed in a traveling exhibit to the various Chapters. They will be returned to the owners in May 1956 if so desired.

Classification of Micros

BLACK AND WHITE PRINTS

1. Carbon and alloy steels
2. Stainless steels and heat resisting alloys
3. Iron, cast and wrought
4. Aluminum, magnesium, beryllium, titanium and their alloys
5. Copper, nickel, zinc, lead and their alloys
6. Metals and alloys not otherwise classified
7. Series showing transitions or changes during processing
8. Welds and other joining methods
9. Surface phenomena
10. Results by unconventional techniques (other than electron micrographs)
11. Slags, inclusions, refractories, cermets
12. Color micros (prints; no transparencies accepted)

Rules for Entrants

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable. Photographic prints shall be mounted on stiff cardboard; maximum dimensions should be limited to 15 by 22 in. Heavy, solid frames are not permissible because of difficulties in mounting the exhibit. Entries should carry a label on the face of the mount giving:

Classification of entry
Material, etchant, magnification
Any special information as desired

The name, company affiliation and postal address of the exhibitor should be placed on the BACK of the mount.

Transparencies will NOT be accepted.

Entrants living outside the U.S.A. should send their micrographs by first-class letter mail endorsed "Photo for Exhibition—May be opened for customs inspection." To be acceptable as first-class mail the package should measure no more than 35 x 45 cm. (14 x 18 in.)

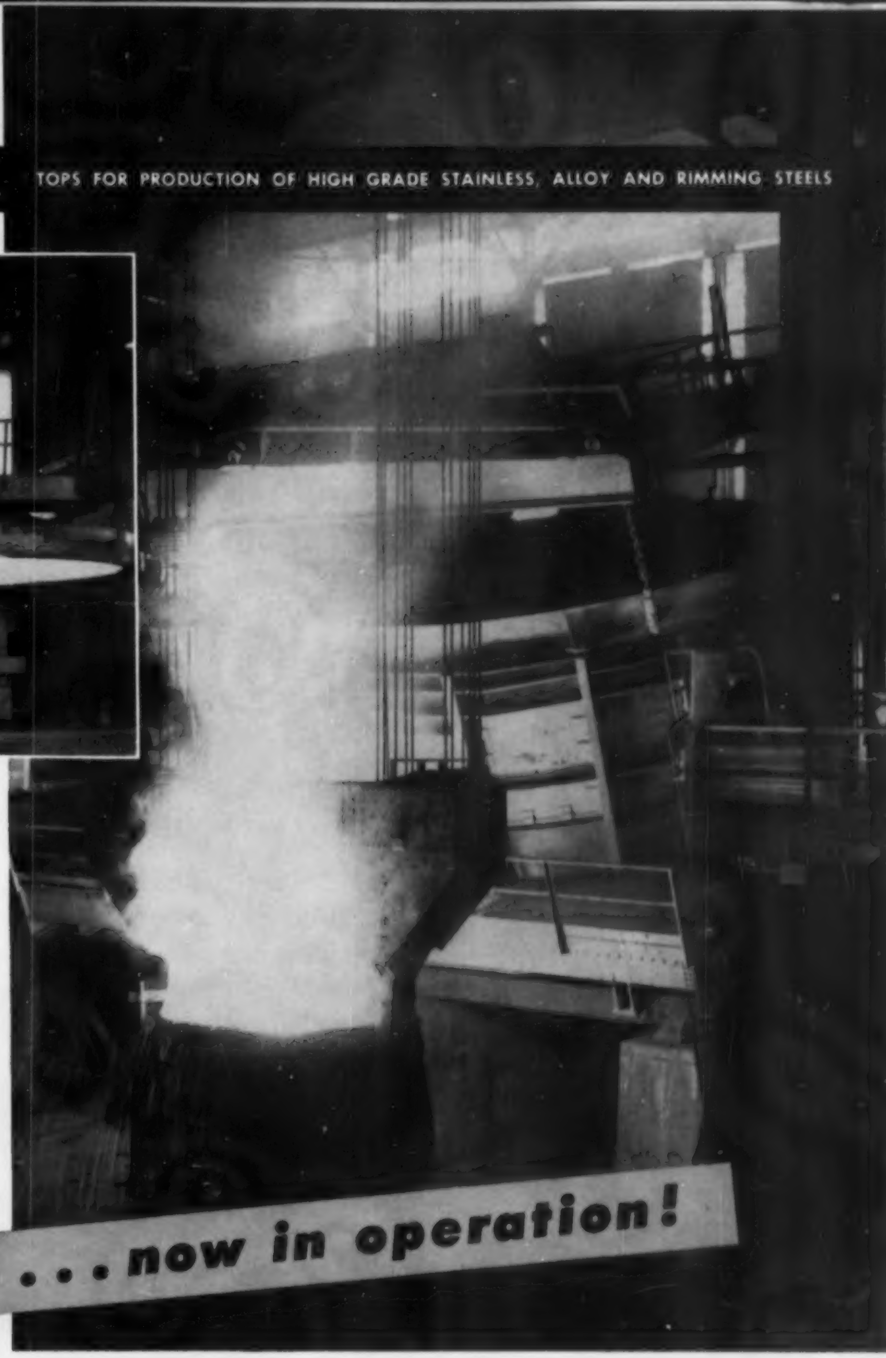
Exhibits must be delivered before Oct. 10, 1955, either by prepaid express, registered parcel post or first-class letter mail, addressed to:

A.S.M. Metallographic Exhibit
National Metal Exposition
Convention Hall
Philadelphia 4, Pa.

37th National Metal Congress and Exposition

Philadelphia 4, Pa. **October 17 to 21, 1955**

Heroult ELECTRIC MELTING FURNACES



World's Largest Electric Furnaces

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McLouth's adoption of electric furnaces of this size sets a precedent. It is a "first" which should conclusively prove that, in addition to closer control, higher uniformity, better performance, and greater safety, large capacity Heroult Electric Furnaces are an economically sound investment—even for high tonnage steel-making.

We welcome an opportunity to help you select and install the furnace best suited to your particular requirements.

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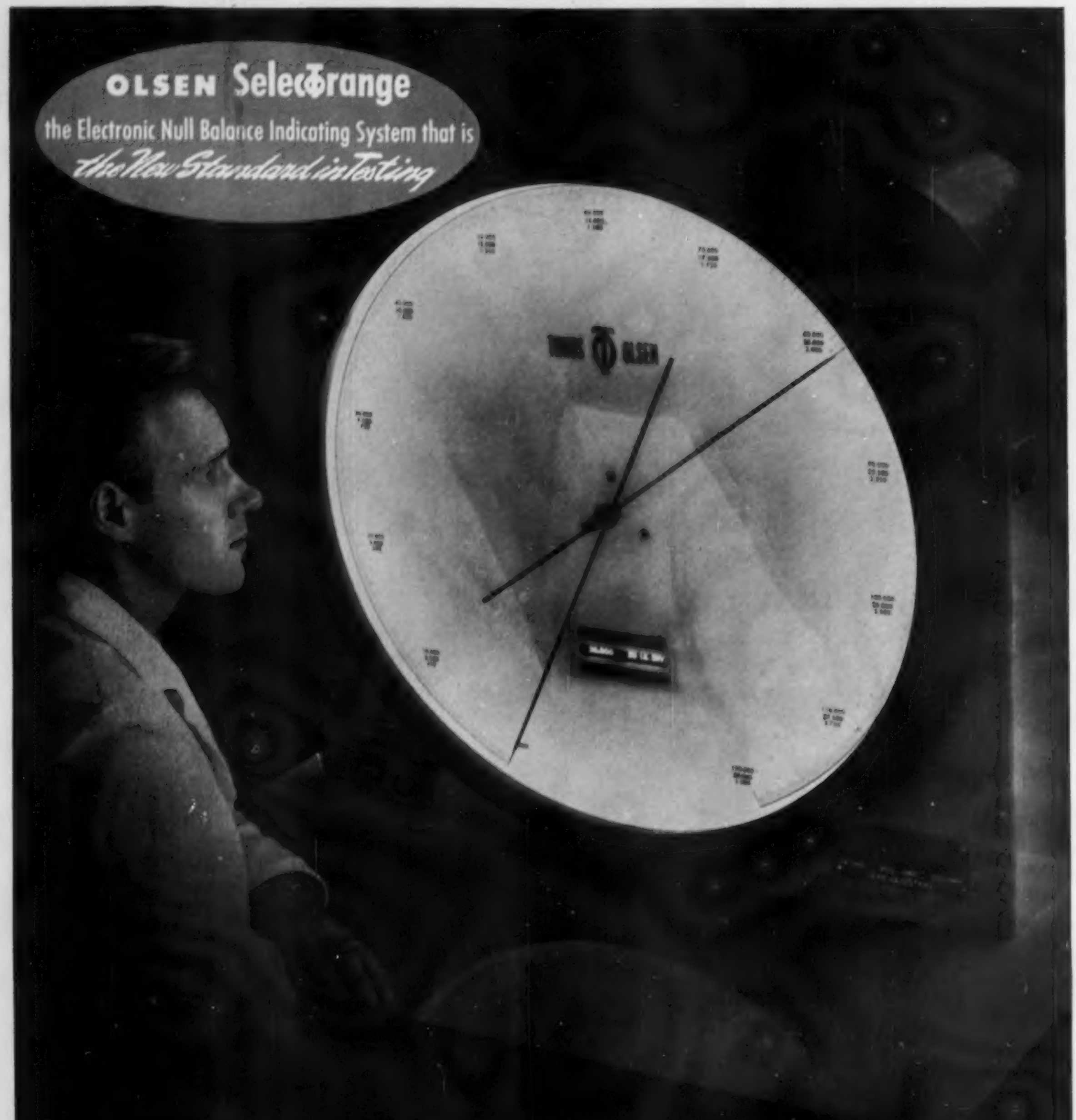
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the Electronic Null Balance Indicating System that is
the New Standard in Testing
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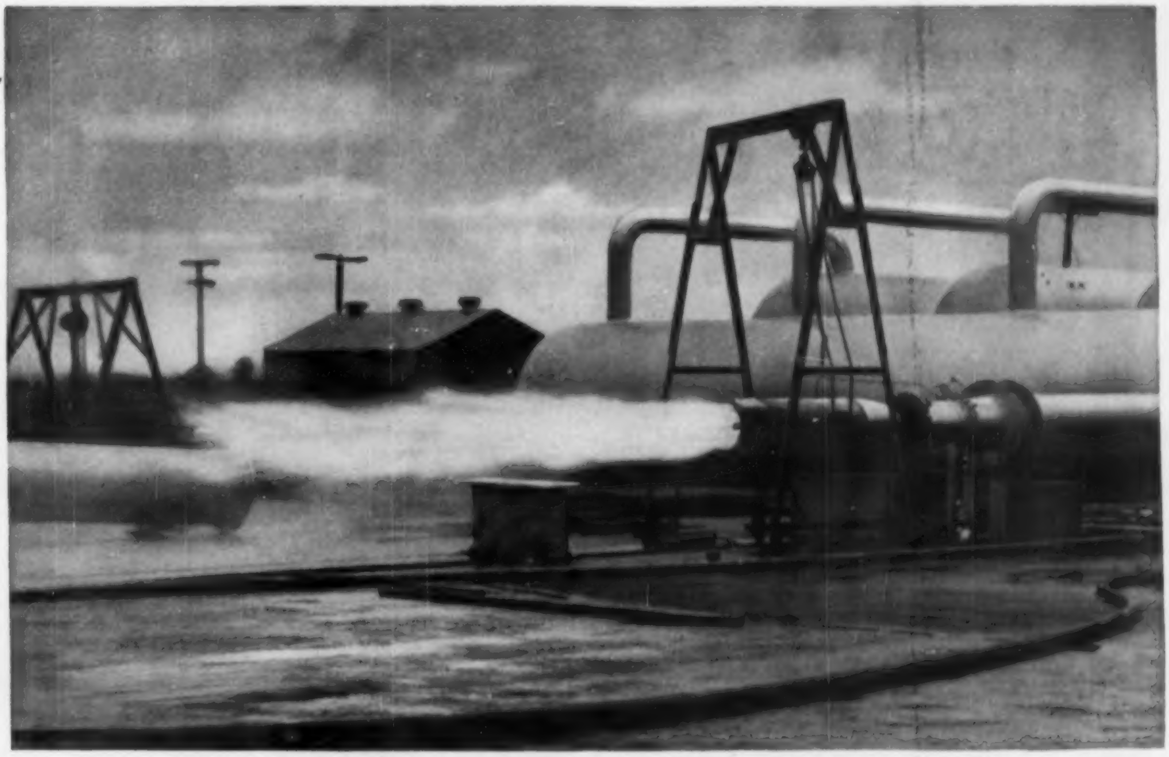

Ramjet tailpipes withstand severe abuse. (*Photo courtesy Marquardt Aircraft Company*)

MULTIMET Alloy Controls the Blast of Ramjet Engines

Tailpipes used to direct the searing blast of power in today's ramjet engines must withstand temperatures in excess of 2000 deg. F, plus severe vibration. High-speed ramjets operate in the neighborhood of 1500 mph. At these high speeds, vibration is almost as serious a threat to tailpipe life as heat. Because of its strength at high temperatures, MULTIMET alloy has given good service in tailpipes that vibrate as much as three inches.

Ramjet tailpipes are made of MULTIMET alloy sheet that is only 0.051 to 0.078 in. thick. The combined high-temperature strength and oxidation resistance of MULTIMET alloy permits the use of lightweight tailpipes with good heat-transfer properties.

MULTIMET alloy is one of many HAYNES alloys capable of extending the life of parts used at high temperatures. For literature describing the properties of HAYNES high-temperature alloys, get in touch with the nearest Haynes Stellite Company Office.

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Remember the word LECTRODRYER when you need DRYing help. For a free copy of the book, *Because Moisture Isn't Pink,* write Pittsburgh Lectrodryer Corporation, 317 32nd Street, Pittsburgh 30, Pennsylvania.

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PRODUCT:
Fork lever

MATERIAL:
Steel

EQUIPMENT:
250 kv x-ray machine

Kodak Industrial X-ray Film, Type A

THIS steel fork lever was designed to take a specific load. But shrink, if present, would rob it of its strength. So the radiographer was called upon to check for soundness.

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Type A—has high contrast and fine grain with adequate speed for study of light alloys at low voltage—heavy parts at intermediate and high voltages. Used direct or with lead-foil screens.

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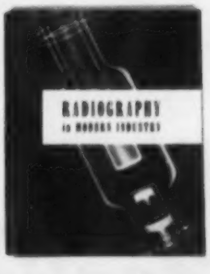

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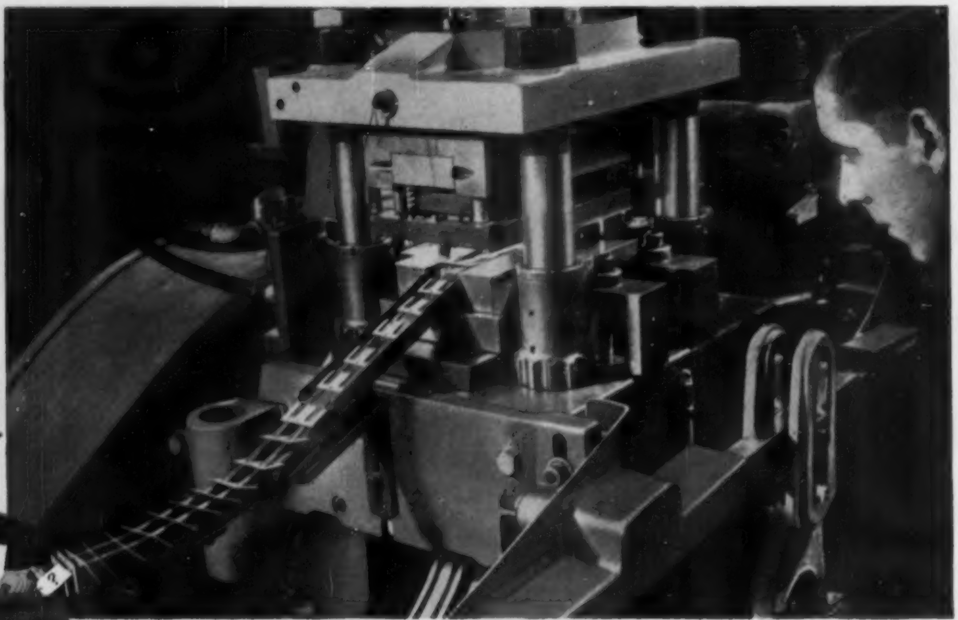
Kodak

Photo courtesy Magnetic Metals Co. shows automatic production of power transformer laminations with DIECARB dies.



Mr. Tooley Says:

"There are two sides to every question"

CROMOVAN

HIGH CARBON—
HIGH CHROME STEEL

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- **Better edge wear**
- **Safe to heat treat**
- **Easier to machine**

DIECARB

THE HIGH PRODUCTION CARBIDE

- **Made expressly for blanking and lamination dies.**
- **High resistance to shock and abrasion.**
- **Low regrinding cost.**
- **Greater production per die life.**

The question of which die material to use for blanking and laminating operations involves a choice of either *steel* or *carbide.* Consideration must be given to the factors which determine die life, such as abrasiveness of the material to be worked, burr limit, distortion of product or elimination of subsequent machining operations.

In the selection and purchasing of die materials, Firth Sterling offers you *unique* advantages because it manufactures *both* steel and carbide. From *one* dependable source of supply you are assured of completely *un*biased recommendations and the *right* steel or carbide or *both* for every die making need.

Typically, Firth Sterling DIECARB and Firth Sterling CROMOVAN (die steel) are widely used for blanking and laminating operations, depending upon job requirements. Write today for literature and unbiased recommendations for your specific needs.

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Biographies of Authors . . . in this issue

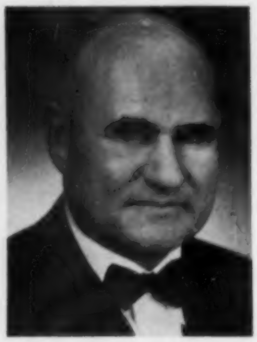
Carl L. Ipsen

The highly respected executive vice-president of the Industrial Heating Equipment Assoc. was a Kansas farm boy but got a Bachelor's degree in electrical engineering from Kansas State College in 1913. He was immediately recruited by General Electric Co., and remained with that firm throughout his business career, with the exception of a two-year stint in World War I with the U. S. Navy. On release from the services, Ipsen was put into the industrial heating department, first as sales engineer, and became successively its chief engineer, sales manager, and general manager, which latter position was held in 1953 on his retirement. During World War II, Ipsen was one of Uncle Sam's dollar-a-year men, being chief of the industrial heating section of the "Blue Eagle" N.P.A.

V. N. Krivobok

Famed nearly as much for the personality behind his presentation of professional papers as for their technical excellence is Vsevolod N. Krivobok. Russian-born and educated, he came to America in 1915 as a junior member of an Artillery Commission sent by the Czarist Government. Five years later he entered Harvard for graduate work, and in 1924 joined the staff of Carnegie Institute of Technology. For some years he divided his time between teaching and directing research at Allegheny Steel Co., and at this time his interest in the then new stainless steels was developed. Between 1941 and 1944 he was director of structural research and later chief metallurgist for Lockheed Aircraft Corp., and in 1944 joined the development and research division of International Nickel Co. Krivobok has generously given his time and talents to many important metallurgical programs. For example, he is vigorously directing a cooperative study of welding techniques for columbium-stabilized stainless steel, sponsored by electrode manufactures, steel producers, equipment builders, the chemical industry and the U. S. Atomic Energy Commission.

Zay Jeffries



Zay Jeffries is undoubtedly America's outstanding metallurgist, the fitting successor of Howe and Sauveur as member of the National Academy of Sciences. President of the American Society for Metals in 1929, the year when plans were made for *Metal Progress*, his sound advice has been of vital importance to the Editor on several critical occasions. Since 1914 he has been consultant and then technical director of the incandescent lamp department of General Electric Co., in 1945 becoming G. E. vice-president in charge of the newly formed chemical department. He retired in 1949 but has continued his service to the nation, serving as chairman of the technical advisory panel on materials for the Department of Defense. A biographical appreciation was printed in *Metal Progress* for May 1941. E. E. T.

Henry H. Hausner

Henry Hausner was born in Vienna in 1901, received his professional education at the Technical University in Vienna (electrical engineer in 1924) and was granted a doctorate in engineering from the same institution in 1938. As a young engineer he worked on the design and construction of power plants but became more and more interested in problems

of illumination; the middle 1930's found him in charge of research for an Austrian incandescent lamp factory. This turned his attention to the fascinating field of powder metallurgy. He imigrated to the United States in 1940 and all his time since then has been spent in research, development and production of powder metallurgy and ceramics. Joining the staff of Sylvania Electric Products, he became manager of engineering of the firm's atomic energy division in 1952. Hausner is a prolific author and finds time also to serve as adjunct professor at Brooklyn Polytechnic Institute. He is general chairman of the forthcoming symposium on powder metallurgy to be held at the convention in Philadelphia, sponsored by the U. S. Atomic Energy Commission.

Abner Brenner

Abner Brenner, author of the review of 25 years' progress in finishing and plating (p. 113), received a B.A. degree in 1929 from the University of Missouri, M.S. degree from the University of Wisconsin in 1930, and a Ph.D. from the University of Maryland in 1939. He has been on the staff of the National Bureau of Standards since 1930 and is now chief of the electrodeposition section. Some of the subjects which have occupied his attention at the Bureau are alloy deposition, the physical properties of electrodeposits, electroless plating, electrodeposition of metals from nonaqueous mediums, cathode diffusion layers, and thickness gages for electrodeposits.

David W. Lillie

Dave Lillie is one of the brilliant young men that G. E. is gathering to man the rapidly expanding metallurgical and ceramic section of the research laboratory at Knolls. Just nine years ago, Dave Lillie turned his interests to atomic energy, joining the Massachusetts Institute of Technology's "Metallurgy Project" operated for the U.S. Atomic Energy Commission; he quickly became group leader in physical metallurgy. In 1948 he was moved to the Washington office of the A. E. C.'s division of research as assistant to the chief of metallurgy and materials and in 1951 became chief. This service has fitted him for his present work at Knolls, investigating some long-range problems in nuclear materials.

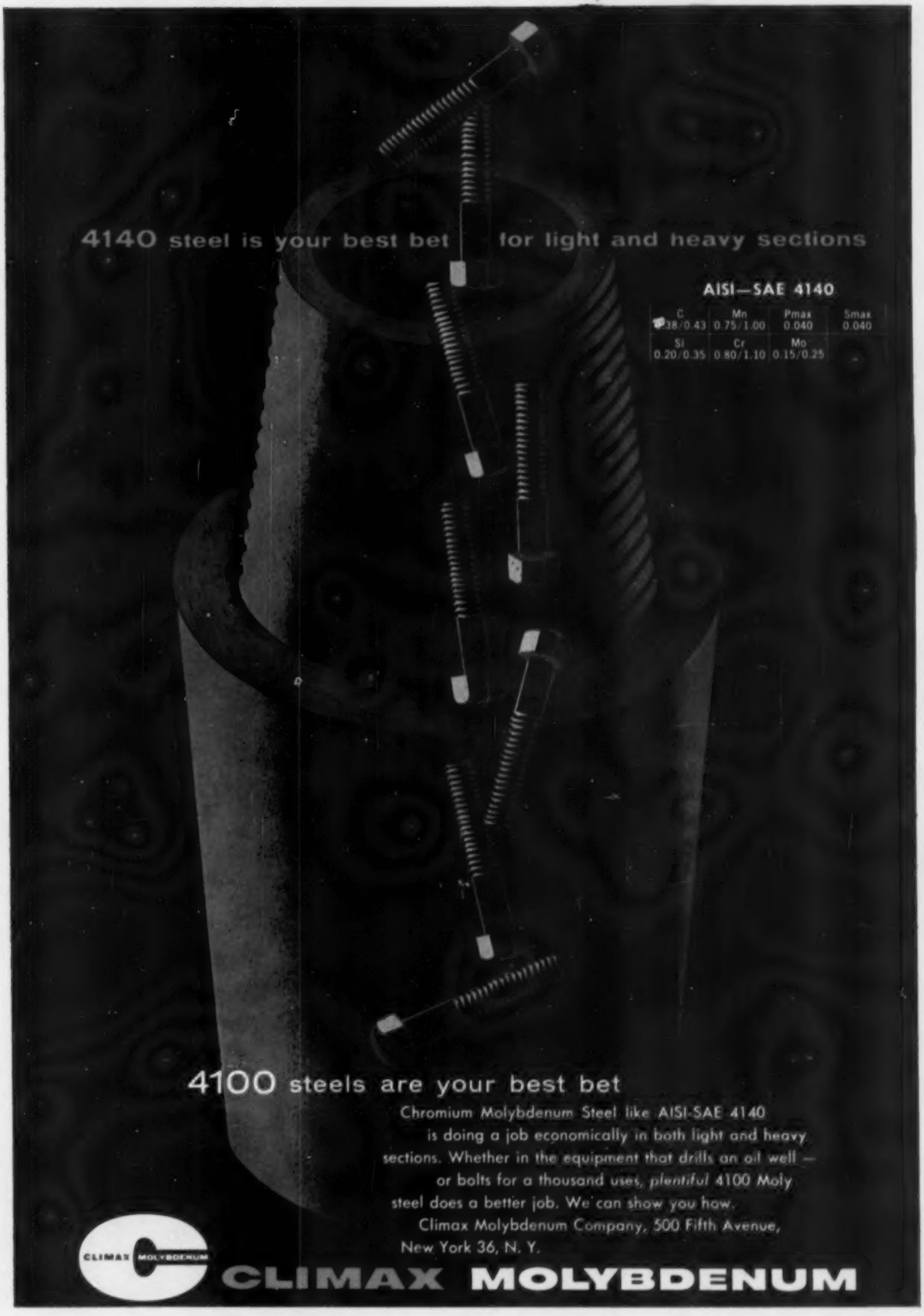
Lillie has a bachelor's degree in chemistry from Harvard. Between graduation (1939) and his work for the A. E. C. (1946) he was at the old Atha works of Crucible Steel Co. of America, becoming assistant superintendent of heat treating and later superintendent of the tungsten carbide department.

John R. Freeman, Jr.

John Freeman looks like a prosperous Yankee man of affairs – indeed he is one, having been born in Winchester, Mass., educated in Massachusetts Institute of Technology, and is culminating 25 years of work with American Brass Co., now holding down the position of vice-president, metallurgy and research. His degree is Bachelor of Science in Electrochemistry. Very soon after graduating from M.I.T., he joined the metallurgical staff of the National Bureau of Standards (1917) where he stayed until 1930 – with the exception of one year with Rosenhain and Hansen at National Physical Laboratory in England as "exchange research worker" on the iron-nickel diagram – being assistant chief of the metallurgical division when he resigned to join the technical department of American Brass Co. Some of his notable work at the Bureau of Standards included equipment and methods for testing properties of metals at elevated temperatures, and a long series of studies on fatigue and internal transverse ruptures in rails which finally pointed to the source and cure of this dangerous defect.

At Waterbury, where he was successively assistant and then manager of the technical department before becoming vice-president of the company, Freeman participated in no small degree in many of the notable advances in copper and its alloys he describes in the article on p. 85.

(More authors' biographies on page 238)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Max W. Lightner

Getting his B.S. at Penn State in 1929, Max W. Lightner went to Carnegie Tech for his Master's degree, and stayed on as research engineer for Uncle Sam's Metallurgical Advisory Board until 1933. He then went to Homestead Steel Works and became assistant general superintendent (1940-1942) in various steps leading through the position of chief metallurgist. 1942-1944 saw a break in his employment by the U.S. Steel Corp. or one of its subsidiaries; he spent those years as vice-president, operations, for Heppenstall Steel Co. Late in 1944 he rejoined Carnegie-Illinois as manager of the research and development division, and his responsibilities were expanded to cover the entire Steel Corporation in 1951. Since 1954 he has been assistant vice-president, research and technology, for U. S. Steel Corp.

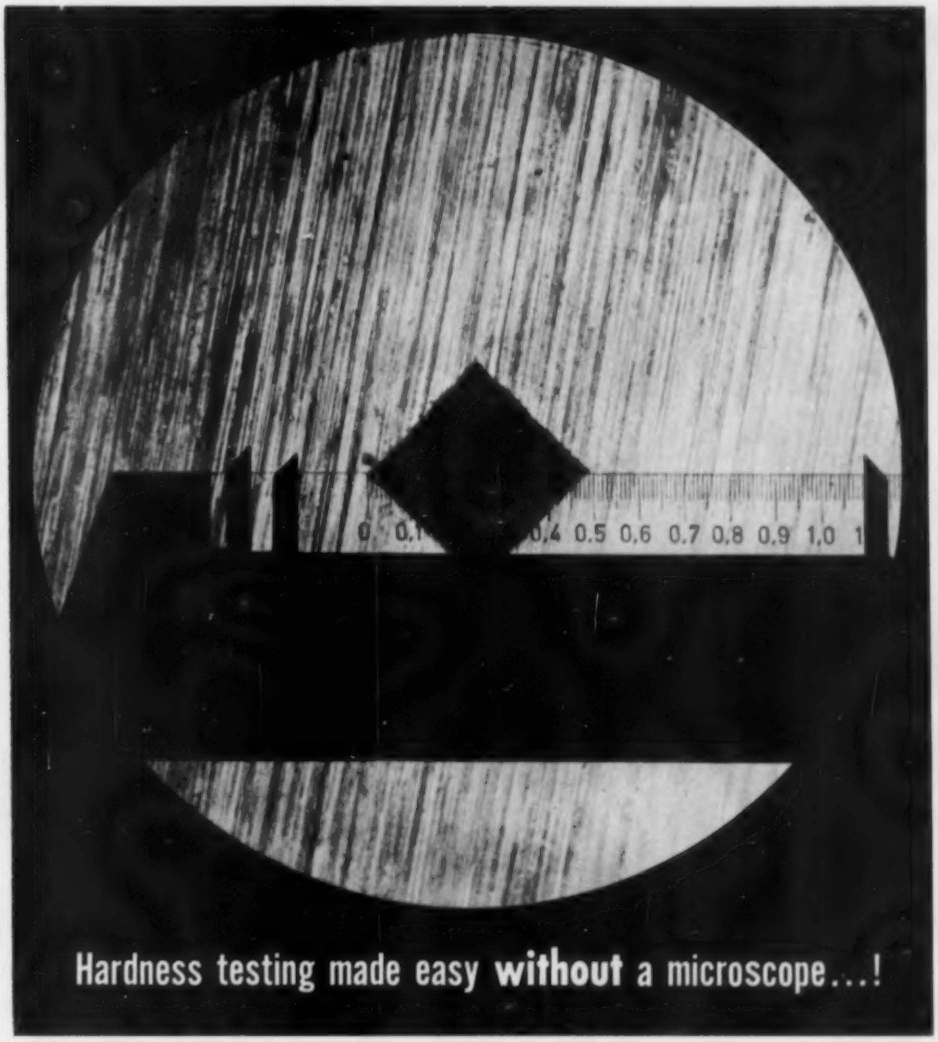
Cyril Stanley Smith

When Cyril Smith was awarded the United States Medal of Merit for his work at Los Alamos during the last war, it became immediately apparent that he automatically rated what honor *Metal Progress* could bestow by printing a biographical appreciation, and this appeared in the issue for February 1948. For three critical years, 1943 to 1946, he was associate division leader and had charge of the metallurgical work on fissionable materials for the atomic bomb. After he had left Los Alamos to establish the Institute for the Study of Metals at the University of Chicago, his connection with atomic energy was by no means ended, for by presidential appointment he served on the general advisory committee of the U. S. Atomic Energy Commission until 1952. At present he is on leave of absence from the University of Chicago, studying various aspects of the history of science.

British-born and educated (University of Birmingham, 1924), he joined the staff of the American Brass Co. in 1927 and was asked to organize a research department – an assignment he accepted on condition that he "be asked to do nothing practical". Then (in the words of an associate, a "practical" brass man) "the icons began to fall; gradually answers began to appear for things that were lifelong mysteries." This digging for the origins of things metallurgical – the Science of Metals – has become his life work. The situation and its future prospects he appraises in the article on p. 137.

L. A. Danse

The intensely human document on the "Metallurgy in Mass Production", p. 38 of this issue, could not be improved upon. The author's experience with his topic is unique, for he grew to a high position in the automotive industry, advancing by sheer native ability. Almost all of his working years have been spent with some subsidiary of General Motors Corp. – first as superintendent of heat treat for Dayton Engineering Laboratories, then for 25 years with Cadillac. Starting there in 1929 as chief metallurgist, he immediately planned many mechanized operations in heat treatment and continually gave much attention to specifications for incoming material and to production control of metallurgical manufacturing operations. From 1943 to his retirement in 1954 his activities widened to that of technical advisor on manufacturing operations ("trouble shooting", he would call it) for all units of General Motors Corp. He is particularly proud of his work in these last years in instituting schemes for control of water and air pollution – for which G. M. spent some $43,000,000. This enthusiasm originated in a love of outdoors gained in his youth – he was born in Montana and his father (miner and prospector) took him far and wide in the Rocky Mountains. For this same reason he is proud of the Silver Beaver awarded him as 35-year veteran Boy Scout Master, and his honorary vice-presidency of the American Forestry Assoc. Always quick to recognize a good thing, Danse is one of the handful of metallugists who organized the Steel Treating Research Club of Detroit – one of the root stocks form which A.S.M. sprang. A biography of "L. A." appeared in *Metal Progress* for November 1952. (*More biographies on page* 240)



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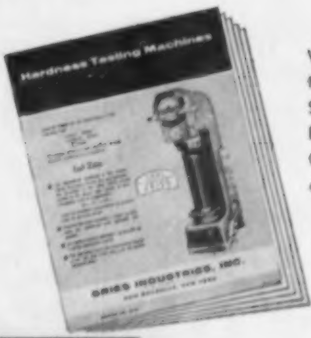

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Walther Mathesius

Born in Hoerde, Germany, from a long line of teachers, ministers, and engineers, Walther Emil Ludwig Mathesius emigrated to the United States shortly after receiving his Doctorate in Engineering. He got a job at the blast furnaces of South Works, Chicago, and was on his way, rising to superintendent of the department (1917-1925) and making such improvements and growth in output of the furnaces as to warrant the Clamer medal of the Franklin Institute. His skill in management was later proved in his service as general manager of operations of the Chicago district of Carnegie-Illinois Steel Corp.; vice-president, operations, U. S. Steel Corp., and president of Geneva Steel Co. Since 1951 he has been engineering consultant for Koppers Co. In Geneva he proved his ability as a diplomat by so effectively placating violent opposition to the establishment of heavy industry in a peaceful Mormon valley that he was awarded an honorary degree by Brigham Young University, the second "gentile" to be so honored in history. A biographical appreciation of Walther Mathesius was published in the April 1940 issue of *Metal Progress.*

Roger A. Long

An Ohioan by birth and education (B.S. in Chemical Engineering, Ohio State University, 1943) Roger Long's varied experience has been closely connected with aircraft engines, although he has found time to study enough law, on the side, to be admitted to the Ohio Bar. He worked for Lockheed Aircraft Corp. as metallurgist in the production engineering department, for National Smelting Co. on secondary aluminum alloys, and for P. R. Mallory & Co. on aluminum-clad bearings. Much of the time since 1943, however, was with Lewis Flight Propulsion Laboratory, N.A.C.A., as metallurgist and aeronautical research scientist. His title was chief, metallurgical branch, when he resigned in 1954 to become manager of aircraft components division of Ferrotherm Co. of Cleveland.

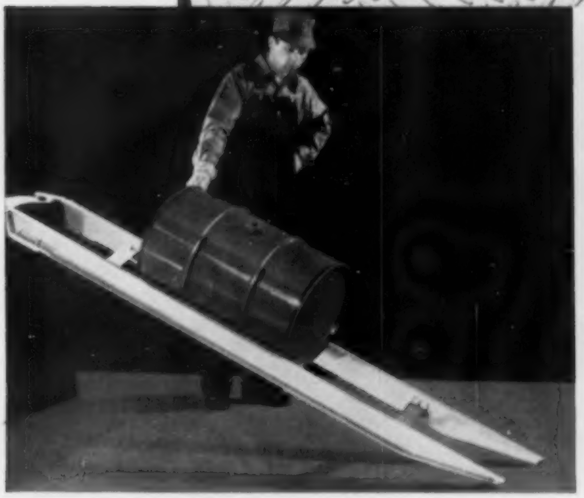
During his service with N.A.C.A. he did a great deal of work on high-temperature materials, air-cooled turbine blades, protective coatings and turbine blade design, and his name is signed to many patents issued in these fields. His published N.A.C.A. reports are on the manufacture and properties of high-purity molybdenum, sintered and wrought, and on fabrication of hot-pressed molybdenum disilicide.

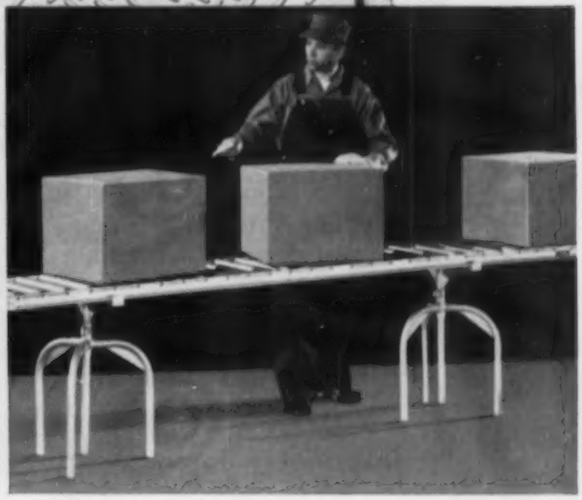
Don M. McCutcheon

Don McCutcheon enjoys many distinctions. One fascinating one is that he runs a consultation, research and development firm on the salubrious shores of Madeira Beach, Fla. A native Detroiter and M. S. in metallurgical engineering from Ann Arbor, he was a member of Ford Motor Co.'s staff, becoming director of the applied physics unit of Ford's manufacturing research department. He was manager of the physics department of the new scientific laboratory in 1952 when failing health required a complete change in living habits. McCutcheon was president of the Society for Nondestructive Testing in 1948 and chairman of the Detroit Chapter in 1950. He has written and lectured extensively on various aspects of radiation – X-ray inspection and analysis, particularly – and has devised gages whereby radioactive isotopes may locate the height of liquid iron in foundry cupolas and control thickness of cold rolled strip. Present activities of his firm, Macner Development Co., are in atomic power and other aspects of nucleonics engineering.

A. B. Kinzel

No better words can be chosen to characterize the author of our welding article, page 129, than were used when he received the Morehead Medal of the International Acetylene Assoc.: "For the many sound and important advances contributed





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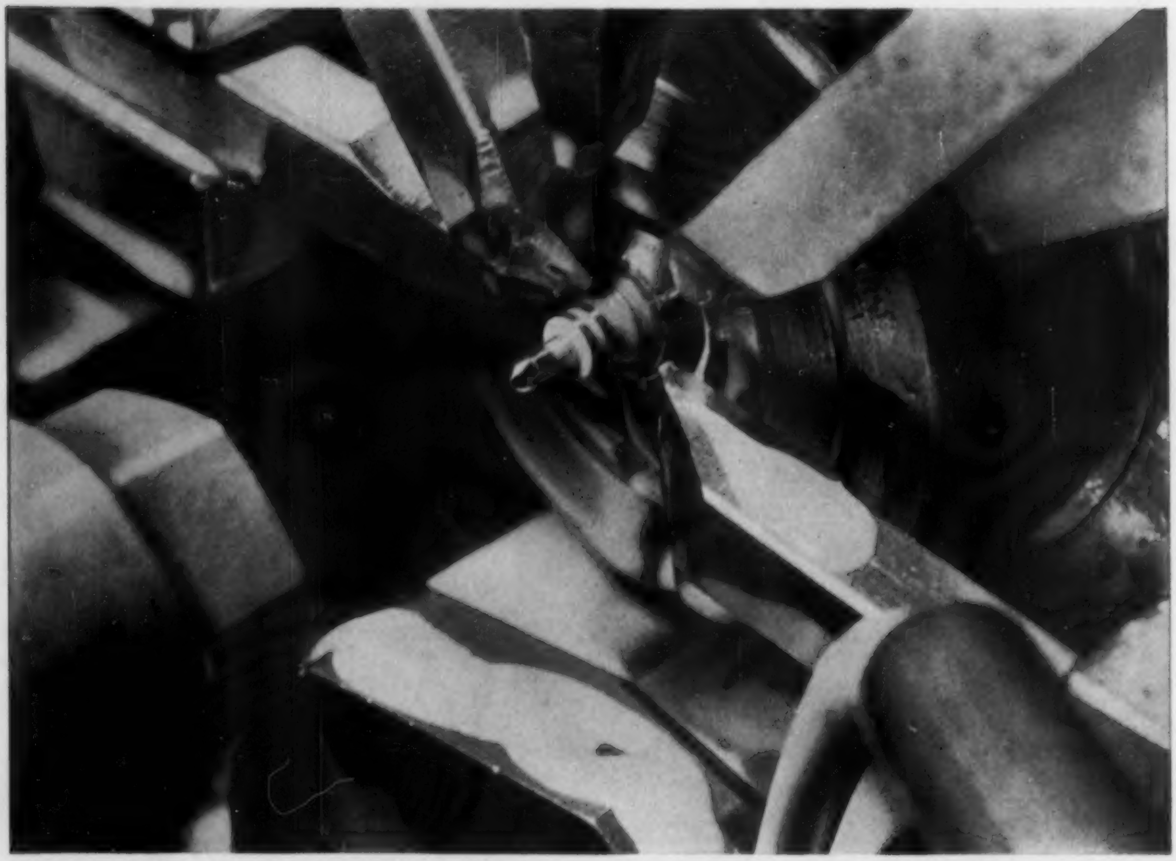
to welding science and technology; for his forthright courage in presenting new ideas, his facility in explaining them, and for his willingness to share with all the fruits of his sound thinking, his fertile imagination and his contagious enthusiasm." As indicated in *Metal Progress* for August 1953, p. 90, "Gus" has been with the Union Carbide & Carbon Corp., since his employment as research metallurgist in 1926. In the years he has advanced rapidly. Early giving intent study to the welding process, his activities widened to include the important metals produced by Electro Metallurgical Co. He is now vice-president in charge of research of all the subsidiaries. One little-advertised aspect of Kinzel's life is the time he has devoted to national affairs – he having been one of the wartime consultants to the Manhattan District's Los Alamos Laboratory. He is also chairman of the Naval Research Advisory Committee.

George W. Cannon

George W. Cannon is the Cannon in Campbell, Wyant & Cannon Foundry Co., the Muskegon (Wis.) firm so well known to the automotive and gas engine industry. When only 14 years old he was an apprentice in a foundry in his home town of Springfield, Ill., but worked so hard at the job and at a correspondence school course that he became a journeyman molder at 18. Seven years later he pooled his $1000 with an equal sum from two buddies, Donald J. Campbell and Ira A. Wyant, and bought a little foundry in Muskegon. Their first real contract was for motor blocks from a neighbor, Continental Motor Corp., and three foundrymen were hired. Thus started what is now, in all probability, the world's largest noncaptive gray iron foundry. The partners decided almost immediately to avoid jobbing business and to specialize. For many years they made just five types of automotive castings, concentrating all energy on consistently high quality at lower costs. The techniques so learned were adopted for many important items of ordnance during World War II such as aircraft brakes and steel tank treads. Mr. Cannon in those years was chairman of the Foundry Industry Advisory Committee to the War Production Board, and for this and his other achievements was awarded the gold medal of the Gray Iron Founders' Society.



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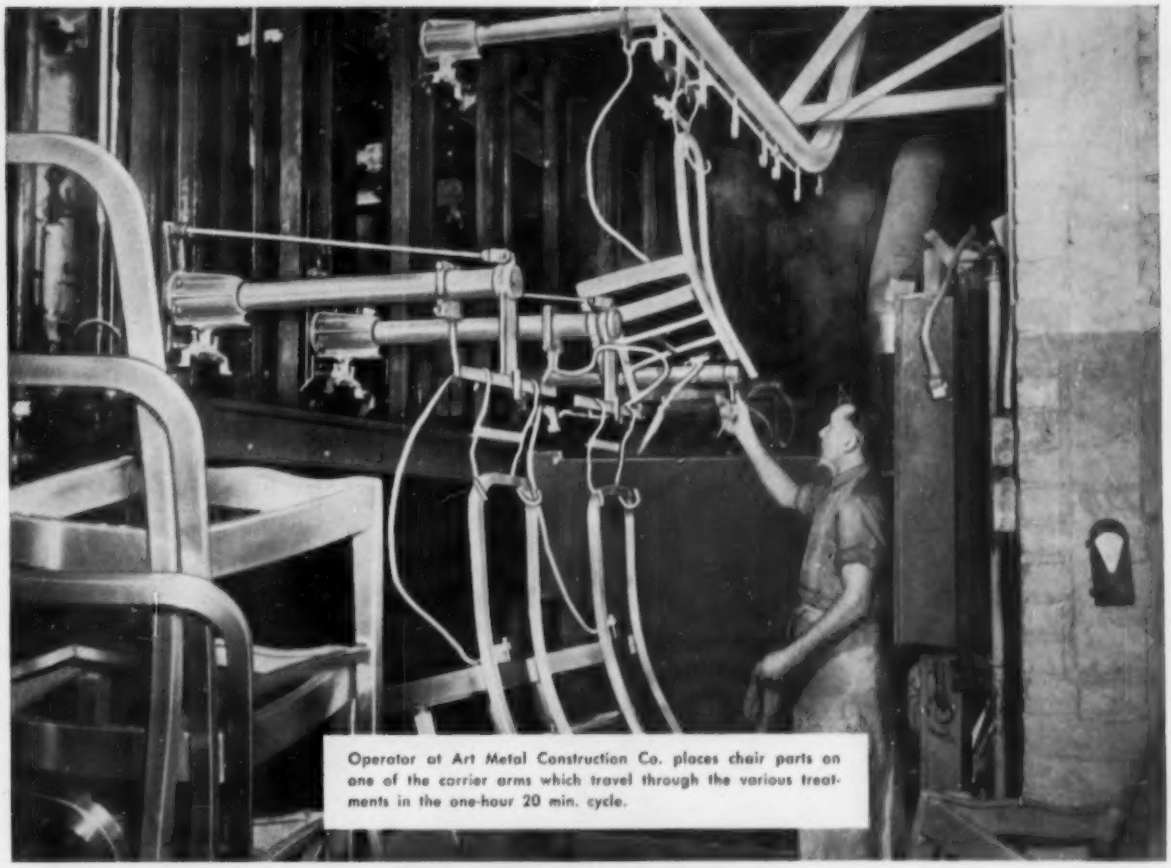

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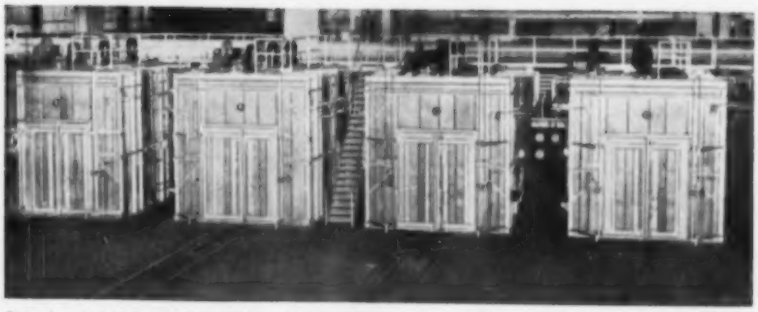

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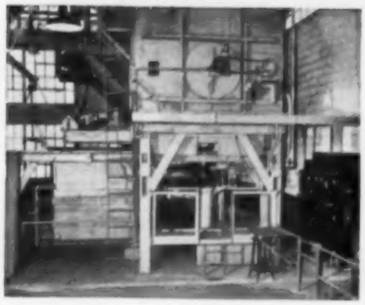

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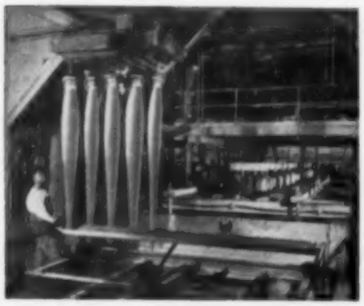

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